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Development of a Checklist for Evaluating Emergency Procedures Used in Nuclear Power Plants

Prepared by R. L. Brune, M. Weinstein

HPT, Inc.

Sandia National Laboratories

Prepared for
U.S. Nuclear Regulatory
Commission

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ABSTRACT

This report describes the process for developing a checklist to be used by United States Nuclear Regulatory Commission Office of Inspection and Enforcement (I & E) inspectors during their evaluation of emergency procedures used in nuclear power plants. The objective of the checklist is to aid inspectors in identifying procedural characteristics that can lead to reactor operator performance deviations. Four nuclear power plants were surveyed to obtain a sample of procedures and related information for human factors evaluation. In addition, a human factors analysis of 890 LERs submitted during the period 1975 through 1978 was performed to identify the major categories of performance deviations associated with reactor operator activities. Checklist items aimed at preventing these performance deviations or facilitating their early detection were developed. The study findings supporting the procedures evaluation criteria comprising the checklist items are described in this report. A companion document, Checklist for Evaluating Emergency Procedures Used in Nuclear Power Plants, NUREG/CR-2005, SAND81-7074, has been prepared as a handbook for inspectors. It describes the checklist and provides instructions for its use.

SUMMARY

In March 1980, HPT Inc. (Human Performance Technologies) began a study of emergency procedures used in nuclear power plants. The study was completed in March 1981. The objective of the study was to develop a checklist to aid U.S. Nuclear Regulatory Commission Office of Inspection and Enforcement (I & E) inspectors in identifying procedural deficiencies that can result in operator performance deviations.

A sample of emergency procedures was gathered from four plants participating in the study. The plants were selected to represent as many factors as possible that might affect the design of procedures. The age of plant, reactor manufacturer, owner, and location were considered. Before visiting the plants, the study team first spent one week at the Combustion Engineering, Inc., simulator facility to become acquainted with operator simulator training, particularly as it relates to training for emergencies. During the plant visits, discussions were held with training personnel and operators regarding operator training programs, again with emphasis on training for emergencies. Documents describing operator training policy were also acquired. In addition, operators performed walk-throughs of the emergency procedures with members of the study team. Data pertaining to the training of operators for emergencies, the format and content of emergency procedures, and the use of procedures in emergencies were obtained.

In addition to the preceding data, an analysis of abstracts of LERs submitted by all plants during the four-year period 1975-1978 was performed. The purpose of the analysis was to identify the kinds of performance deviations that are associated with reactor operator activities. The findings concerning emergency procedures and operator performance deviations contributed to the development of a 46-item checklist for evaluating emergency procedures. The checklist and instructions for its use are presented in Checklist for Evaluating Emergency Procedures Used in Nuclear Power Plants, NUREG/CR-2005, SAND81-7074.

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The study could not have been accomplished without the support of many individuals and organizations. Special acknowledgment is due to Alan D. Swain of the Sandia Statistics, Computing, and Human Factors Division, who provided technical direction and assistance, and to James C. Stone, Acting Chief, Reactor Programs Development Section, Division of Program Development and Appraisal, Office of Inspection and Enforcement, U.S. Nuclear Regulatory Commission, who, as program manager, coordinated the study activities with the NRC Regional Offices and provided critical review and guidance during the study. Thanks are also due to Regional personnel who aided the study team. The efforts of J.R. Buchanan, Assistant Director, Nuclear Safety Information Center, Oak Ridge National Laboratories, and members of his staff to provide personnel error data are appreciated.

The generous assistance offered by the staff of the Combustion Engineering, Inc., simulator facility to introduce the study team to operator simulator training was invaluable. Lastly, the study team especially wishes to acknowledge the support and cooperation they received from the managers and personnel at the four plants participating in the study.

CHAPTER I

INTRODUCTION

HPT Inc. was awarded a contract by Sandia National Laboratories* in March 1980 to develop a checklist for evaluating emergency operating procedures used in nuclear power plants. The work was funded by the United States Nuclear Regulatory Commission Office of Inspection and Enforcement (I & E). The checklist is designed to be used by I & E inspectors as an aid in identifying deficiencies in emergency procedures that could result in operator performance deviations.

The work was based to some extent on the work that Sandia and others performed in the Reactor Safety Study,** and methodology developed by HPT to construct a checklist for evaluating maintenance, test, and calibration procedures used in nuclear power plants.*** This report presents the methodology used to develop the checklist and describes the study findings on which the checklist is based. A companion document, Checklist for Evaluating Emergency Procedures Used in Nuclear Power Plants, NUREG/CR-2005, SAND81-7074, presents the checklist and describes methods for applying it to evaluate emergency procedures.

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*Hereinafter referred to as Sandia.

**WASH-1400 (NUREG-75/014): Reactor Safety Study—An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, U.S. Nuclear Regulatory Commission, Washington, D.C., Oct. 1975: Main Report, Appendix II—Fault Trees, Appendix III—Failure Data.

***Brune, R.L. and Weinstein, M., Development of a Checklist For Evaluating Maintenance, Test, and Calibration Procedures Used in Nuclear Power Plants, NUREG/CR-1368, HPT Inc., Thousand Oaks, CA, May 1980.

CHAPTER II

DESCRIPTION OF STUDY

The major tasks for accomplishing the study are shown in Figure 2.1 and are described below.

Task #1. Preliminary Selection of Study Variables

The first study task was to perform a preliminary selection of the study variables. This objective was achieved at a coordination meeting held by representatives from the Office of Inspection and Enforcement, Sandia, and HPT at the outset of the study. The emergency procedures to be studied were selected, access to a training simulator facility for orientation of the study team was arranged, and nuclear power plants were identified for participation in the study.

Titles of Emergency Procedures

Titles of procedures for combatting emergencies and other significant events are listed in Appendix A of Regulatory Guide 1.33, Revision 2, February 1978. This document specifies quality assurance program requirements for nuclear power plant operations. Ten emergency procedures were selected from this document. The titles are listed in Table 2.1.

Table 2.1 Emergency Procedures
(or Their Equivalent) Selected for Analysis

1. **Loss of Coolant**
2. **Loss of Instrument Air**
3. **Loss of Feedwater**
4. **Reactor Trip**
5. **Loss of Electric Power**
6. **Loss of Condenser Vacuum**
7. **Turbine and Generator Trip**
8. **Loss of Service Water**
9. **Loss of Core Coolant Flow**
10. **Loss of Automatic Reactivity Control System**

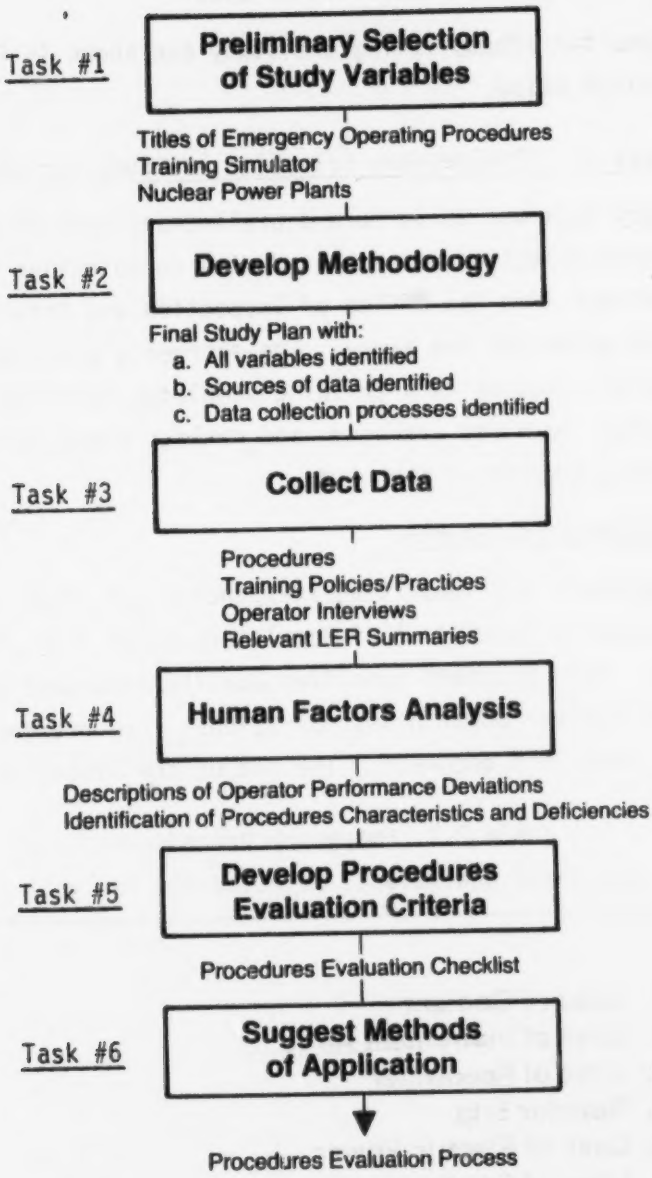

Figure 2.1 Technical Approach for Developing the Checklist to Evaluate Emergency Procedures

It was planned to perform walk/talk-throughs with control room operators of as many of these procedures as time permitted at each plant.

Training Simulator

Although the purpose of the study was to develop a method for evaluating emergency procedures, they cannot be evaluated adequately without knowledge of how they are used and knowledge of other related information that operators possess. What operators do in response to an emergency or impending emergency condition is a function of all of the information they can bring to the situation—both information conveyed by means of procedures and information imparted through training.

In order to gain acquaintance with operator training, particularly as it pertains to emergency responses, the study team requested a one-week visit to a control room simulator facility. Two classes of operators were observed performing simulator exercises. Classroom sessions were attended and training materials were obtained for subsequent study.

In addition to observing operator training at the simulator, the study team asked for permission to interview operators about their training for emergencies and about their use of procedures in responding to emergencies. The purpose of the interviews was to help define more precisely the variables that should be studied, and to plan the collection of data relating to these variables.

Nuclear Power Plants

It was anticipated that nuclear power plant licensees would present a wide variety of approaches to the format and content of emergency procedures. These procedural characteristics are a function of the regulatory requirements in existence at the time a plant is licensed for operation, past practices of plants in the preparation and use of emergency procedures, and responsiveness of the utility to post-licensing experiences and information relative to the design of emergency procedures. Therefore, it was decided to select plants representing a broad spectrum of on-line dates as well as reactor types and suppliers. Four

plants were selected. Reactors from each major supplier, General Electric, Westinghouse, Babcock and Wilcox, and Combustion Engineering, were represented. The plants came on-line between 1969 and 1979.

Task #2. Develop Methodology

To be usable, the emergency procedures must have several characteristics.

1) They must be technically accurate.
2) They must be complete with regard to the information needs of the operators.
3) They must be understandable, i.e., format, vocabulary, and sentence structure must present procedural content in a way that is readily comprehensible at the time the procedure is used. The design of the procedure must take into account the effects of stress on perception, comprehension, and retention.

The first characteristic, the technical accuracy of procedures, depends upon the quality of engineering analyses supporting the development of the procedures. The evaluation of a procedure for technical accuracy consists, for the most part, of comparing the procedure with engineering documents. The third characteristic, understandability, can be achieved by use of appropriate, detailed procedures specifications. Ideally, evaluation is performed by inspecting the procedure for compliance with the specification.

The second characteristic, completeness of information with respect to the information needs of the user, is perhaps the most difficult characteristic to achieve and to evaluate. It is implicit that one must work from a definition of user capabilities. If there is no clear definition of user knowledge and skills, it is obvious that a procedure might not provide the user with the kind and amount of information required to perform an activity effectively. A complicating factor is that the information needs of users change with time and experience. In most cases, memory will decay with the passage of time. A procedure that is not repeated or rehearsed periodically will be remembered incompletely. Thus,

a procedure that is regarded as complete one time, might be judged as incomplete at a later time. On the other hand, if a procedure is repeated frequently, persons may regard it as being overly detailed and, indeed, cumbersome to use as a result of these experiences. However, emergencies, by their very nature, are not frequent events. Operators are unlikely to have job experience in actually performing specific emergency procedures, although they may have considerable experience in performing some of the tasks comprising the procedure. If the investigation of the use of emergency procedures disclosed that specific tasks contained in them are not rehearsed or performed periodically, reliance must be placed on the contents of the procedure itself to provide the users with the information needed to respond to the event—even to the point of being considered too detailed. Reliance should not be placed upon memory in high-stress situations.

Because of the above considerations, it was important that data concerning operator training for emergencies and operator use of emergency procedures be obtained during plant visits. Therefore, it was requested that access to control room operators and training personnel be made available so that these groups could be interviewed about these topics. In addition to these sources of information about operator training, the study team requested copies of corporate policies and plant directives dealing with operator training for emergencies.

The direct assistance of operators was required to perform walk/talk-throughs of the emergency procedures. It was requested that they be performed in the control rooms. Geographical proximity to the equipment involved in the procedure served to remind operators of details of the emergency activity that might otherwise be overlooked. It also enabled them to perform walk-throughs of tasks to demonstrate physical relationships between equipment and the compatibility of task sequences with job requirements. It should be pointed out that no human engineering evaluations of control room equipment or workspace layout were made by the study team since they were not within the scope of the

project nor were such evaluations necessary for the development of procedures evaluation checklist criteria.

One final source of information bearing on the effectiveness of operator performance is Licensee Event Reports (LERs). Nuclear power plant licensees are required to report events that jeopardize the effectiveness of safety-related systems. These events are coded according to probable cause with keywords such as maintenance error, design error, procedure error, operator error, etc. Relatively few of the LERs deal specifically with operator performance during emergencies. However, the LERs are a relevant source of information for determining the kinds of errors operators make in the performance of plant operations in general, during both emergency and routine activities. Procedures evaluation criteria aimed at reducing the frequency of operator errors in emergencies can be derived from the LER data.

Printouts of abstracts of LERs submitted by all licensees for the four-year period 1975 through 1978 were obtained from the Nuclear Safety Information Center, Oak Ridge National Laboratories. All LER abstracts coded as procedure errors or operator errors were selected for analysis of operator performance deviations.

The final study plan was prepared. The study variables and the sources of data regarding each variable are summarized as follows:

Variable	Sources of Data
Operator training for emergencies	Simulator observations Operator interviews Training personnel interviews Policies and directives dealing with operator training for emergencies
Use of emergency procedures by operators	Operator interviews
Format and content of emergency procedures	Copies of emergency procedures Descriptions of procedures development and updating processes
Operator performance deviations	Abstracts of LERs related to operator errors

Task #3. Collect Data

One-week visits were scheduled at each of four plants. The objectives of the study and the plant support that would be needed to fulfill these objectives were explained to the plant managers. Control room operators were made available for interviews and walk/talk-throughs of emergency procedures. Because of unanticipated operational problems, the control room at one plant was not accessible for walk-throughs. Administrative problems precluded the use of a control room at another plant. In both instances senior control room operators reviewed the procedures with the team member. In the two remaining plants, it was possible to complete the walk/talk-throughs of all 10 procedures.

Training personnel were interviewed at each plant. The interviews focussed on operator training for emergencies. Copies of corporate policies or plant directives pertaining to operator training were also requested.

Task #4. Human Factors Analysis

The objective of the procedures analysis was to provide a detailed description of the characteristics of the emergency procedures. These characteristics were, in turn, reviewed in the light of findings regarding operator training, operator use of emergency procedures, and operator performance deviations. The findings enabled the investigators to evaluate which of these procedure characteristics represent procedural deficiencies that can result in operator performance deviations. Procedures evaluation criteria were developed from the findings to aid I & E inspectors to identify safety-related deficiencies.

Task #5. Develop Procedures Evaluation Criteria

The criteria for evaluating the emergency procedures were entered on worksheets that listed the operator performance deviations identified from the analysis of LERs. The procedures evaluation criteria were then judged with respect to their relationship to the kinds of operator

performance deviations reported by licensees. It was required that each criterion be relevant to the correction of one or more performance deviations. The criteria meeting this qualification were retained for further consideration as checklist items. The output of this activity was a checklist for evaluating emergency operating procedures.

Task #6. Suggest Methods of Application

The checklist is intended to aid I & E inspectors in identifying procedures deficiencies that can result in operator performance deviations that impact on risk. The inspectors already have a heavy workload and only part of their time is available for evaluating procedures. Therefore, it was important that efficient methods of using the checklist be developed. The output of this function was a description of a method for using the checklist to yield an effective and efficient procedures evaluation process.

CHAPTER III

ANALYSIS AND FINDINGS

The analysis dealt with four different topics:

- Operator Training in Emergency Responses
- The Role of Emergency Procedures in Operator Responses to Emergencies
- Operator Performance Deviations
- Characteristics of Emergency Procedures

The analyses were performed independently of each other. The findings from these separate analyses were then synthesized and used to develop procedures evaluation criteria. The findings are described in the following sections.

Operator Training in Emergency Responses

Written policies and/or directives concerning operator training were obtained from each of the four plants visited. Statements bearing on operator training in emergency and abnormal events were extracted from these documents. Information about three characteristics of training was sought—the frequency of training, the method of training, and the evaluation of training. Capsule summaries of the written policies are presented in Table 3.1.

Operators and training personnel were questioned about actual plant practices with respect to emergency training. Representative responses are summarized in Table 3.1. One of the questions concerned the use of simulators, which in none of the plants visited is required by written policy. For the most part, operators are sent to simulators for training one week a year.* The simulators are regarded as useful for demonstrating functional relationships between process systems. They are not necessarily used for training in emergencies or abnormal events. In some instances, the simulator staff prepares the curriculum; in other cases the plant staff provides varying amounts of input to the content

*Utilities that own simulators provide simulator training as frequently as every six weeks as part of their ongoing operator refresher training program.

Table 3.1 Operator Training in Emergency and Abnormal Events

Plant	Policy*	Practice
A	Review abnormal and emergency procedures twice a year. Review by lecture or on-the-job training (OJT). Evaluate by written exams.	Schedule is not maintained. Training is on overtime. Review emergency procedures about every two years. Review by reading and discussion. The formal training in emergency procedures is viewed as "no good" so the operators use OJT. They study "what to do" rather than a procedure per se. The procedures have known errors. The emphasis is on understanding the system. Operators receive simulator training once a year but believe it has dubious value because of differences between plant and simulator. The plant makes input into the content of the simulator training course.
B	Review all abnormal and emergency procedures every six months. Review by lecture or OJT. Evaluate by annual oral exams.	Procedures are read every six months. The bulk of training is OJT. The operators do not memorize the procedures, which have known errors, but rely instead on understanding the plant and common sense. Operators receive one week of simulator training per year, half of which is classroom training. The simulator staff prepares the curriculum.
C	Requalification training, in part devoted to training in abnormal events and emergencies, is on a two year cycle. Training is by lecture (four hours per month), individual study and OJT. Evaluate by annual written exams, continuous oral exams and "walk throughs" as needed.	The operators review all emergency procedures every two years. Review by reading and discussion. There are known errors in the procedures, but the training emphasizes emergency responses based on understanding of the system rather than rote memory of the procedures. Operators receive simulator training once a year. The plant prepares its own curriculum.
D	There are six 2 hour lectures per year. One lecture is devoted to the topic **Normal, Abnormal and Emergency Procedures.** No statements are made regarding the review of procedures. No statements are made pertaining to evaluation of operator knowledge.	One 2 hour lecture per year is in part devoted to emergency procedures. In addition, the operators review emergency procedures every six months. There is no formal evaluation. Operator signoffs indicate that the procedures have been reviewed. Operators receive simulator training every one or two years. The plant prescribes its own simulator training curriculum. Emphasis is on accidents. Simulator training is viewed as fairly valuable. Because of differences between plant and simulators, briefings and debriefings are required. Operators and training personnel do not think training program is adequate. It is being modified.

*No written policy requires simulator training.

of simulator training courses. Oftentimes, the simulator does not physically represent the plant control room. It was also found that operators are sometimes scheduled for training on simulators that are not representative of the reactor used by the plant. Simulators are in such high demand compared to the number in operation that they are sometimes selected almost solely on the basis of availability. Some operators objected to the dissimilarities between the plant and simulator. Also, there was a desire to spend more time on the simulator rather than to follow present practices of half simulator time and half classroom time at the simulator facility. The idea of plants acquiring simulators specific to their control rooms was endorsed by operators and training personnel alike.

It appears that operators place their confidence in on-the-job training where they learn the functional relationships between their specific plant systems and develop the skills to manipulate plant equipment. Their training emphasizes emergency responses based on understanding of the plant systems—in contrast to learning emergency procedures per se. In effect, emergency training does not consist of rehearsing written emergency procedures. The procedures are regarded as guidelines rather than instructions to be followed step-by-step. The fact that emergency procedures with known and uncorrected errors exist further underscores the fact that operators view them as guiding documents only.

The Role of Emergency Procedures in Operator Responses to Emergencies

The study team was able to observe operator performance to simulated abnormal and emergency events at the simulator facility. This limited observation, however, provided no information pertaining to the use of procedures in actual situations. The only source of this information was the operators themselves. They were questioned at the simulator site and at each of the plants visited. Discussions were held with 19 licensed control room operators, the majority of whom were senior reactor operators. They represented five different power plants. The

discussions were held with individuals or groups of operators as circumstances dictated. Although the interviews were unstructured, during the course of the interviews the questions listed in Table 3.2 were asked. A summary of representative operator responses accompanies each question.

Two comments most salient to this study involve: 1) the attitudes expressed toward the quality of emergency procedures, and 2) the use of emergency procedures during emergencies. The procedures are viewed as not particularly relevant to coping with an emergency. The contents are regarded as unlikely to reflect the actual emergencies that are experienced. In line with this view, the statement was frequently made that not all emergencies, or not even the course of an individual emergency, can be anticipated and accounted for by procedures. It was commented that there are just too many variables to program into a procedure if the procedure is to be short enough to be usable. In general, the operators were of the opinion that emergency procedures are unlikely to reflect real events and probably cannot be designed to represent real events accurately, at least in a step-by-step manner. The procedures are valued as guidelines and for use in refresher training.

It was found that operators commonly perform immediate actions without first obtaining a procedure. Furthermore, the immediate actions are responses to system performance (as inferred from alarms and displays) and do not necessarily conform to the sequence of actions prescribed by a procedure. In fact, many operators objected to being tested on the sequence of immediate actions in the procedure for this very reason. The sequences provided in the procedure are not necessarily mandatory. In terms of equipment functions, other sequences might be equally effective and, it is generally felt, should be an operator option. After completing the immediate actions, operators obtain the procedures for use in performing subsequent actions.

Table 3.2 Operator Interview Questions and Representative Answers

1. What, in your opinion, is an emergency?

   a. A situation that presents a hazard to public health and safety.
   b. When the system does not respond as anticipated.
   c. When I start sweating.
   d. When a system is not responding the way it is supposed to.
   e. When a system begins to exceed its design boundaries.
   f. When the operator no longer knows what to do to correct a problem.

2. How does an emergency differ from an abnormal operating condition?

   In an abnormal condition I can maintain the system within its design boundaries for some time—although not at a desired level.

3. In general, what do you think of the written emergency procedures?

   a. Not worth the paper they are printed on.
   b. Use it as a training device.
   c. They do not reflect real emergencies.
   d. Too long and cumbersome.
   e. Not detailed enough.
   f. We already know what to do—just refresh our memory without too much verbage (i.e. provide guidelines).

4. Suppose you just decided that you were faced with a small break LOCA, and you have now picked up the proper emergency procedures. What were your actions prior to this point and what do you do next?

   a. Pick it up only after immediate actions are completed. All immediate actions are done.
   b. Start doing the subsequent action.

5. The emergency procedure generally contains three sections, Symptoms, Immediate Actions and Subsequent Actions. How do you use each section and what, in your opinion, is the value of each section?

   Symptoms—for training only. Symptoms are gone by the time the procedure is picked up.
   Immediate Action

   a. No time to read. They must be performed from memory.
   b. Procedure is useful as a training device.

   Subsequent Action

   a. Use procedure as trouble-shooting or diagnostic aid or just to refresh my memory.
   b. Not enough detail.
   c. Too much detail.
   d. Level of detail in small break LOCA looks about right—but too wordy.*

   *Note: The small break LOCA procedure was developed from a recently received reactor vendor fault analysis.

Table 3.2 Operator Interview Questions and Representative Answers(cont'd)

6. Were you involved in the writing of emergency procedures? What analysis, if any, was performed?

   Most operators said "No". The most experienced operators (supervisor or manager) wrote the procedures based on their own experiences. No formal analysis, i.e., fault free, safety path, etc. was performed.

   The exception is the small break LOCA. They are being rewritten according to new guidelines. At one plant, the operators had been consulted on the new LOCA procedure.*

   *Note: The new LOCA procedure was developed from a recently received reactor vendor fault analysis.

7. Do you have any problems in getting changes incorporated in the existing emergency procedures?

   There is generally no difficulty in submitting change requests although the acceptance appears to be rare. As a result, many operators commented on the futility of submitting changes. They tend to leave the error in the procedure and work around it.

8. Would you comment on the level of detail in the written instructions?

   Comments were variable. The less experienced operators preferred more detail than the more experienced ones. They would like to see those instructions that require maintaining or verifying a "normal level" to also tell them what to do if the existing level is found to be below or above that level.

   They don't seem to believe that they can ever become rattled enough to require a high level of detail in the procedure.

9. How are the responses to an emergency coordinated?

   Generally, the level of coordination depends upon the personality of the operators and supervisors. One plant had a policy. Two did not.

   Authors' Note: Emergency procedures themselves do not reflect the need for coordination. Since the LOCA procedures have become more complicated, the need for coordination becomes more acute. There is typically only one set of procedures available but most of the responses are multi-man responses.

10. How would you define an immediate action? When does it start and when does it end?

    An immediate action was generally defined as those steps that must be taken in response to a system alarm to stabilize the system. They are responses that must be committed to memory. Since the

Table 3.2 Operator Interview Questions and Representative Answers (cont'd)

reaction time is short, they are performed in response to the system behavior and not in the sequence that is arbitrarily set down in the procedure. The operators agree that they must be memorized—but in response to a specific set of stimuli—not to the arbitrary sequence in the procedure.

Can't define the end limit clearly. Ideally it is the stabilization of the system but sometimes this can take a long time and diagnostic procedures may be required.

11. At what point in time after the onset of an alarm do you generally begin to suspect that an emergency exists? In other words, when do you generally start the diagnostic process?

Sometimes you become suspicious before the first alarm even goes off. Usually it begins sometime during the immediate actions. The pattern of lights and the sequence of events can tell you a lot.

In other cases, only after the system has been stabilized and after the immediate actions have been completed.

12. Do you consider your training in the use of emergency procedures adequate? Explain.

The answer is generally "No". The in-house training is not considered adequate and is often suplemented by on-the-job (OJT) training programs set up by operations. The simulator training varies in value according to its ability to mimic the plant system. At some plants debriefing is conducted after a simulator session to eliminate negative transfer.

Figure 3.1 depicts a typical pattern of operator responses to an emergency as inferred from discussions with operators by the study team. The illustration is over-simplified in that it does not show recycling of response functions nor does it indicate the interaction of response functions such as diagnosis, manipulation of controls, verification of system responses, further diagnosis, etc. However, it is adequate for conceptualizing a design of emergency procedures that would be compatible with job requirements and, therefore, would enhance the reliability of operator performance during emergencies or impending emergencies. The figure suggests that the existence of an emergency or impending emergency is signalled through audible alarms or, in some cases, through interpretation of visual displays prior to the initiation of alarms. Either category of indicators (displays or alarms) is symptomatic of system conditions. Upon identifying the alarm, the operators

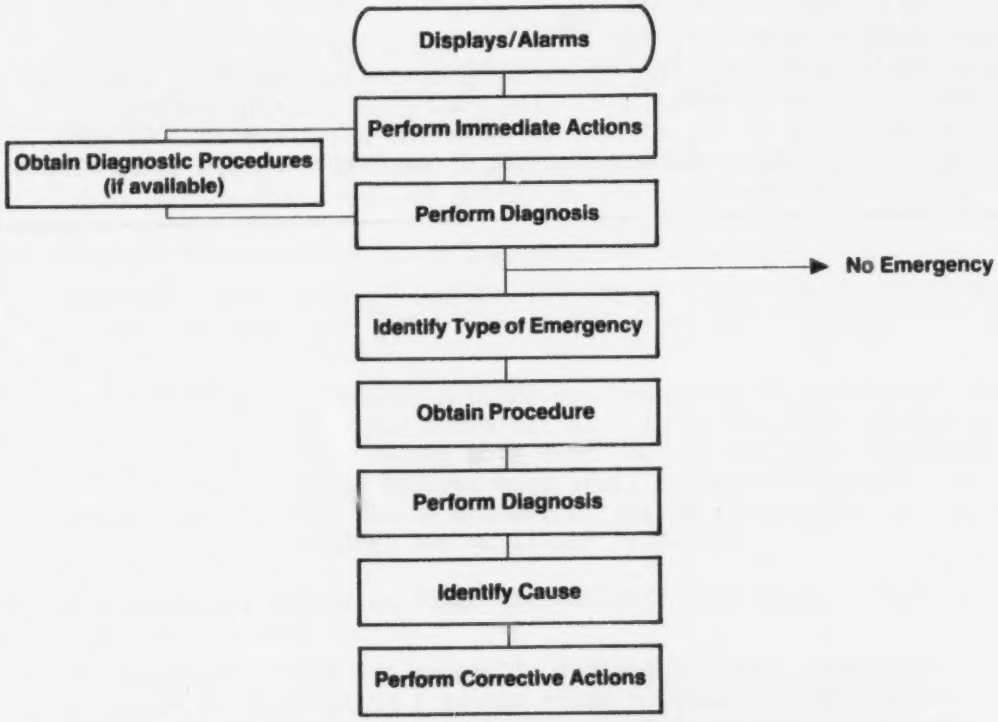

Figure 3.1 Pattern of Operator Responses to Emergency Events—Typical

will perform immediate actions aimed at arresting the condition associated with the alarms. The time delay between identifying the alarms and performing immediate actions will vary, depending upon many factors. In fact, in its broad sense, immediate actions can consist of observing displays as well as manipulating controls. Also, the amount of diagnosis concommitant with performing immediate actions will vary. In some events, diagnosis and verification will accompany the actions. In other events, diagnosis and verification will be delayed until the sequence of immediate actions is completed. In both cases, diagnosis will follow the completion of immediate actions for the purpose of identifying whether or not an emergency exists. In some plants, diagnostic procedures or aids are available to support this process. If it is determined that an emergency exists, the operators will attempt to identify the type of emergency. Only at this point can they select a procedure. If the procedure contains diagnostic information, they can use it to identify probable cause leading to appropriate corrective actions. It appears, then, that a good deal of the response to an emergency or impending emergency is made without a written procedure. The procedure comes into play to verify identification of cause and to prescribe lengthy subsequent actions.

Operator Performance Deviations

It was learned from discussions with operators that a substantial portion of emergency responses, particularly at the onset of an emergency, are made without the use of procedures. After the immediate actions have been performed, a procedure is useful for verifying the initial identification or classification of the emergency, diagnosing the cause of an emergency (when diagnostic information is provided by the procedure), and prescribing subsequent actions. Therefore, to understand emergency responses, it is important to take into account the kinds of errors operators make when they are not using procedures as well as when they use procedures. Emergency procedures can then be designed to reduce the

impact of specific kinds of operator performance deviations either by reducing the probability of their occurrence or by increasing the probability of detecting the errors that have occurred before they impact risk.

The most readily available data pertaining to operator error are yielded by Licensee Event Reports (LERs). Nuclear power plant licensees are required to submit a report to the United States Nuclear Regulatory Commission of any event jeopardizing the effectiveness of safety-related systems. These reports are referred to as LERs. Abstracts of the LERs are on file in the Nuclear Safety Information Center at Oak Ridge National Laboratories. They are coded according to the general categories of errors leading to the events, e.g., maintenance errors, procedure errors, operator errors, design errors, administrative control errors, etc.

It should be pointed out that the vast majority of LERs describe events associated with the performance of routine operations. Only a very small proportion of them result from emergencies. However, the LER data in its entirety does provide a description of human performance deviations in nuclear power plant operations. There is no reason to believe that the performance deviations would be any different in kind in emergencies versus routine activities. If anything, only the frequency of the performance deviations would differ—becoming more frequent under the heightened stress of emergency conditions.

Although the LERs have known deficiencies stemming from inconsistencies and inaccuracies of event analysis and reporting, this deficiency does not detract from their usability for identifying and classifying kinds of operator performance deviations.

A printout of abstracts of all LERs submitted by all licensees during the four-year period 1975-1978 was obtained. For purposes of this study, LER abstracts coded as operator errors or procedure errors were reviewed. These two categories comprised 828 and 813 LERs, respectively, for a total of 1641 LERs. The abstracts were screened for applicability to an operator performance deviation analysis. Many of the abstracts coded as

procedure errors dealt with maintenance procedures and were therefore not relevant to this study. Other LERs described pre-operational activities and were eliminated. LERs that were too brief to permit consistent interpretation and agreement between judges were also deleted. A total of 890 LER abstracts describing operator performance deviations was retained for analysis.

The first task consisted of separating the LERs into two groups. One group consisted of descriptions of operator performance deviations unrelated to the use of procedures. That is, a procedure was not mentioned in the LER nor could the use of a procedure be inferred from the description. The second group was made up of descriptions of operator performance deviations associated with the use (or misuse) of procedures. Procedures were specifically referred to in the LER and/or the cause of the performance deviation was attributed to procedures in the LER or by the study team.

The above groups of LER abstracts were then further analyzed by the following process. Each abstract was read and given a name descriptive of the kind of operator performance deviation associated with the event. Abstracts reporting similar events were grouped together. This process was repeated several times until the reviewers were in agreement with respect to sorting the abstracts into the categories derived from the data. Categories were added, deleted, and redefined throughout the process to achieve this objective. The results of this analysis are described in the following sections.

Operator Performance Deviations Unrelated to the Use of Procedures

A total of 561 LERs described operator performance deviations in which the use of procedures did not appear to be involved. Rather, they were for the most part associated with "skill of the craft" activities for which procedures are not ordinarily used. It was found that five categories of performance deviations adquately accounted for all of the LERs resulting from these activities. They were:

1. Inadequate monitoring and/or controlling.
2. Errors of omission.
3. Inadequate planning and/or decision making.
4. Inadequate communication and/or coordination.
5. Incorrect calculating.

Although these categories are not mutually exclusive, it was possible to assign each LER to one category only.

Figure 3.2 illustrates the relative contribution of each of these kinds of error to the total number of errors reported. The largest category, errors in the performance of monitoring and controlling activities, accounts for 38% of the LERs. This category is followed by errors of omission, comprising almost one-fourth (24%) of the errors operators make in the performance of plant operations. Next are errors in planning and decision making. They account for 17% of the total. Inadequate communi-

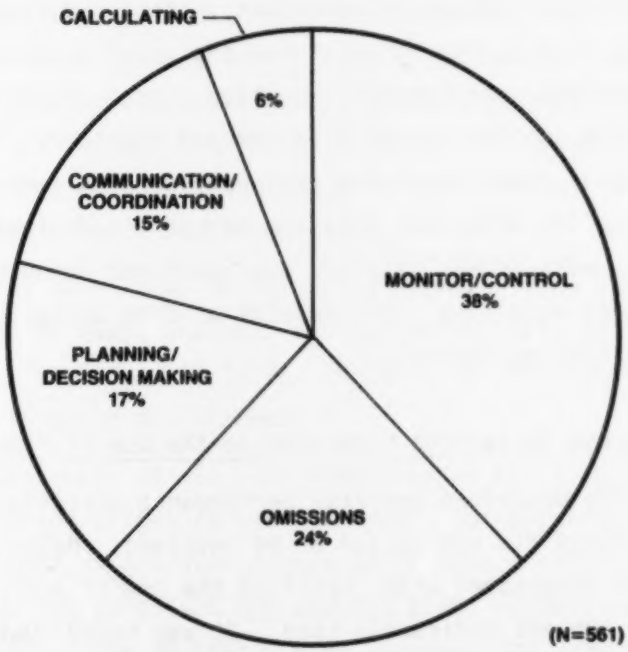

Figure 3.2 Operator Performance Deviations Unrelated to the Use of Procedures

cation and coordination contributes 15% to the total. This category includes errors attributed to misunderstanding oral or written communication and errors described as unauthorized actions. It also includes failures to transmit information at shift changes. The smallest category, errors in performing calculations or extrapolating data, comprises 6% of the total. Based on a previous study*, it is likely that most of the calculating errors are attributable to entering incorrect values into an equation rather than processing the data incorrectly.

In some cases, it was possible to perform a further breakdown of the five major kinds of performance deviations described in the preceding paragraphs. Figures 3.3, 3.4, and 3.5 present breakdowns for, respectively, monitoring/controlling, omissions, and planning/decision making. In Figure 3.3 it is indicated that for monitoring/controlling 50% of the errors are associated with monitoring tasks.

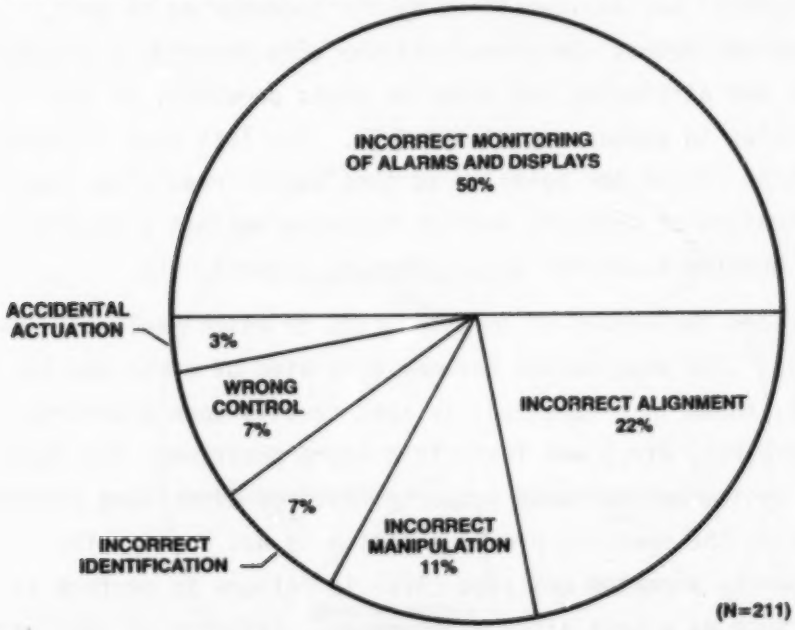

Figure 3.3 Distribution of Monitoring/Controlling Performance Deviations

*Brune, R.L. and Weinstein, M., Development of a Checklist for Evaluating Maintenance, Test, and Calibration Procedures Used in Nuclear Power Plants, NUREG/CR-1368, HPT Inc., Thousand Oaks, CA, May 1980.

Included are errors such as failures to respond to alarms, misidentification of alarms, misinterpretation of displays, and failure to maintain proper control of levels, pressures, flow rates, etc. In the case of controlling errors, comprising the remaining half of monitoring/controlling errors, the LER descriptions were generally more definitive and permitted quantification of the error sub-categories. The largest sub-category was incorrect control alignment, making up 22% of the control errors. Most frequently, the LER reported this error as a failure to align a system correctly for an operation. The error was described as a "misalignment". Incorrect manipulation of controls accounted for 11% of the LERs. Errors consisted of moving a control in the wrong direction, setting a control to a wrong position, and improper sequencing or timing of a control manipulation. Incorrect operator identification of controls occurred in 7% of the events reported. The LERs clearly stated that the control was misidentified by the operator as to unit and/or identification number. Another 7% of the LERs reported actuating the wrong control and attributed the error to close proximity of controls or similarities in appearance of controls. The last type of error, accidental actuation (3% of the total) describes events resulting from unintentional actuation of controls such as brushing against a control with a shoulder, bumping a control while cleaning a panel, etc.

Figure 3.4 partitions the errors of omission, 50% of which deal with improper restoration. The distinction between this kind of error and incorrect alignment, shown in Figure 3.2, is that in this case a control (valve, circuit breaker, etc.) was found in a wrong position. The implication is that a system had not been properly restored after some previous action. Ordinarily, the specific previous action is not known. The second most frequently reported omission (37%) is failure to perform an entire activity, such as a test after maintenance. Failures of this sort might reflect inadequate communication, but are not described as such. Omitting an important action during the performance of an activity accounts for the last 13% of omission errors.

A breakdown of planning and decision making errors is shown in Figure 3.5.

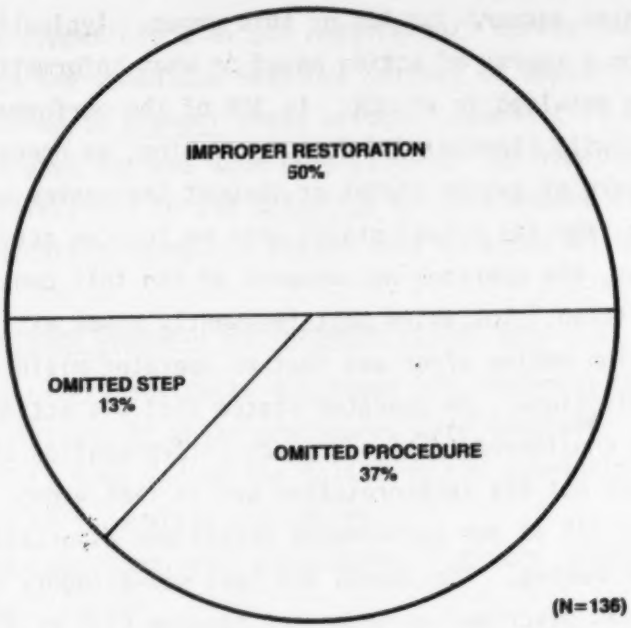

Figure 3.4 Distribution of Performance Deviations Due to Omissions

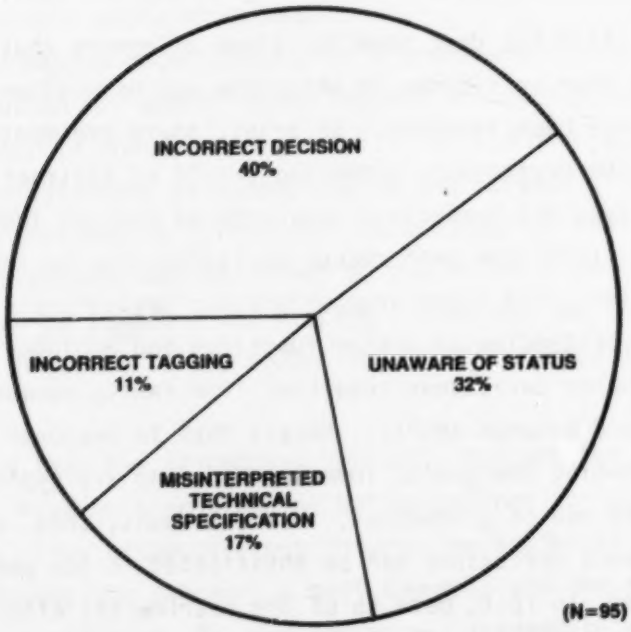

Figure 3.5 Distribution of Planning/Decision Making Performance Deviations

Incorrect decisions account for 40% of this group. Typically, an operator decided upon a course of action based on what information he had, and the decision resulted in an LER. In 32% of the performance deviations associated with planning and decision making, an operator stated that he was unaware of system status or thought the system was in a status different from its actual status when he took an action. Also, in some instances, the operator was unaware of the full consequence of the action undertaken. The third most frequently given explanation for a planning/decision making error was that an operator misinterpreted technical specifications. An operator stated that his actions were based on what he considered to be a correct interpretation of technical specifications but his interpretation was in fact wrong. This factor accounted for 17% of the performance deviations associated with planning/decision making. The fourth and last sub-category of performance deviations was described as incorrect tagging (11% of the total). Most of the errors were planning errors in that incorrect valves were designated for a valve change procedure. Occasionally, an inappropriate valve was manipulated in spite of correct planning and tags.

The preceding section has described the kinds of errors that have been reported for operator activities in which the use of written procedures appears not to have been involved. In brief, there are monitor and control performance deviations, often the result of distractions, misreading of displays, and inadequate knowledge of control functions and characteristics. There are performance deviations due to forgetting (errors of omission), and there are performance deviations attributed to incomplete understanding of system functions and equipment. Also there are performance deviations resulting from faulty communication among operators and between shifts. Recall that in response to an emergency or impending emergency, immediate actions are typically performed without the use of procedures. Without doubt, then, the above kinds of performance deviations can be anticipated in the performance of immediate actions. In fact, because of the detrimental effects of stress accompanying emergency conditions, they will occur with greater frequency than with routine operations. Because the use of a procedure

might not be compatible with job requirements during the onset of an emergency and the immediate response period, it appears that a procedure could do nothing to prevent these errors. However, if a procedure were properly designed for use upon completion of the immediate actions, it could effectively aid in the detection of performance deviations that might have occurred—probably before they effected an impact on risk.

Procedure-Related Operator Performance Deviations

The analysis of LER abstracts disclosed 329 instances of operator performance deviations in which procedures were involved. The performance deviations fell into one of the following six categories:

1. Use of incomplete procedures.
2. Non-compliance with procedures that were judged adequate by the licensee.
3. Use of inaccurate procedures.
4. Faulty communication/coordination in the implementation of a procedure.
5. Use of a wrong procedure.
6. Inadequate understanding of a procedure.

The contribution of each of these factors to total procedure-related operator error is shown in Figure 3.6. The use of procedures that are described by licensees as incomplete is the largest single contributor to operator performance deviations, accounting for 36% of the total. An incomplete procedure was described as one in which information necessary to successful performance was missing. That is, the information was incomplete with regard to the amount and/or kind needed by the intended user.

It was found that the procedures typically are written by subject matter experts who have neither training nor guidelines for preparing procedures. As a result, they often overlook information needed by less experienced persons. Incomplete procedures most commonly are the result of incomplete user analyses although, in some instances, inadequate processes for updating

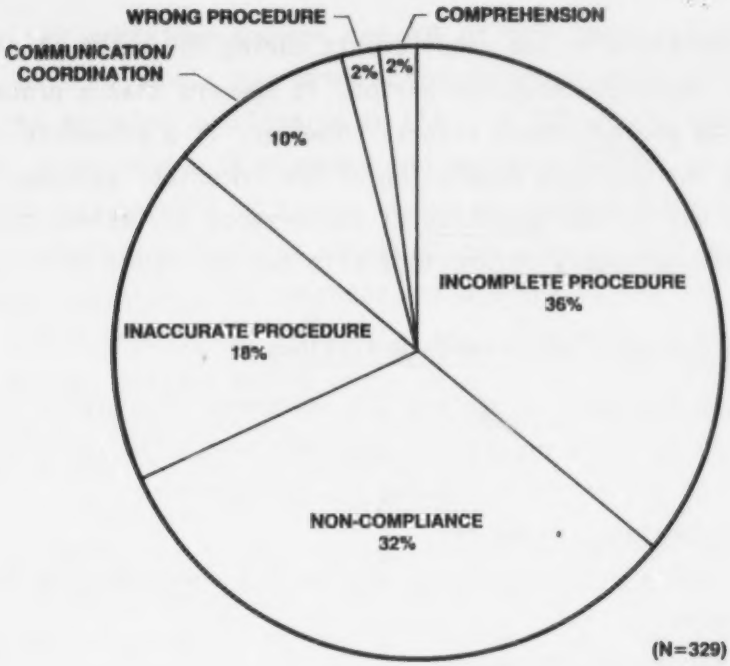

Figure 3.6 Procedure-Related Operator Performance Deviations

procedures can account for omissions of information.

The second leading cause of these performance deviations is non-compliance with a procedure regarded as adequate by the licensee. Almost one-third (32%) of the performance deviations were attributed to this cause. Two forms of non-compliance were discerned: 1) unauthorized actions, and 2) incorrect actions. By an unauthorized action it is meant that a procedure was available but either it was not used or it was not followed. As a result, (a) an action not stated in the procedure was performed, or (b) an action stated in the procedure was omitted, or (c) an action was performed out of the sequence specified in the procedure. By an incorrect action, it is meant that an error was committed in the performance of a step. Most commonly, the operator understood the procedure and intended to follow it but made a mistake such as misreading a display, manipulating a control incorrectly, etc.

Eighteen percent of the performance deviations were attributed to the use of inaccurate procedures. The operator used a procedure containing wrong values, incorrect identification of hardware, incorrect sequence or timing of actions, etc. Just as incomplete procedures result from inadequate procedures analysis or updating processes, so do inaccurate procedures.

Faulty communication or coordination with others in the performance of a procedure accounts for 10% of the operator performance deviations in this category. It is suggested later in this report that the prevention of some portion of these errors is amenable to solution by means of changes in procedures characteristics. For example, the provision of follow-on instructions in procedures would reduce the frequency of these events. So would more structured provisions in procedures for coordinating actions among persons performing multi-man tasks.

The use of wrong procedures, resulting from misidentification of a procedure or incorrect diagnosis of an event, accounted for 2% of the events reported. Failure to understand an instruction in a procedure made up tne remaining 2% of the procedures-related operator performance deviations reported in LERs. The frequency of performance deviations resulting from inadequate comprehension appears low. However, it would be misleading to project this finding to operator performance during emergencies. Comprehension of written instructions is degraded in high-stress situations and the design of emergency procedures must compensate for losses in this ability.

Several of the categories of operator performance deviations permitted a further breakdown of the data. Figure 3.7 shows more specifically the kinds of performance deviations that resulted from the use of incomplete procedures. In 52% of the 122 LERs reporting incomplete procedures, monitor/control performance was adversely affected. Failure to specify operating limits in quantitative terms (as opposed to qualitative terms) accounted for many of these errors. Incorrect alignment of a system prior to performing an activity stemmed from incomplete procedures in

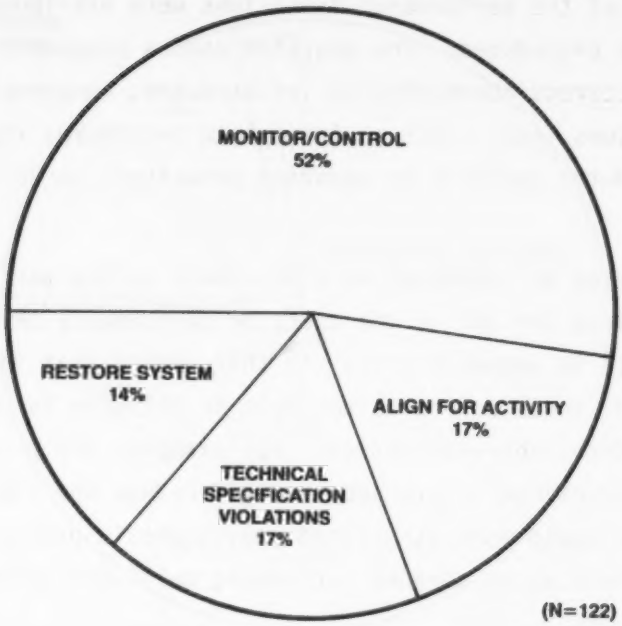

Figure 3.7 Performance Deviations Resulting from Use of Incomplete Procedures

17% of the LERs. Also, in 17% of the LERs the procedures were incomplete with respect to requirements derived from technical specifications. As a consequence, the technical specification was violated. Lastly, failure to restore a system properly upon completion of an activity (usually a maintenance activity) accounted for 14% of these LERs.

Figure 3.8 displays the relative proportions of specific performance deviations attributed to non-compliance with procedures. Thirty percent of non-compliance errors resulted in failures to restore a system after completing an activity. In 26% of the events, either a failure to use a procedure or a failure to follow a procedure led to the omission of important actions. Non-compliance with procedures accounted for monitor/control errors in 24% of the reports. A final consequence of non-compliance with procedures was improper alignment of a system for an activity (service, repair, etc.). Incorrect alignment was reported in 21% of the LERs.

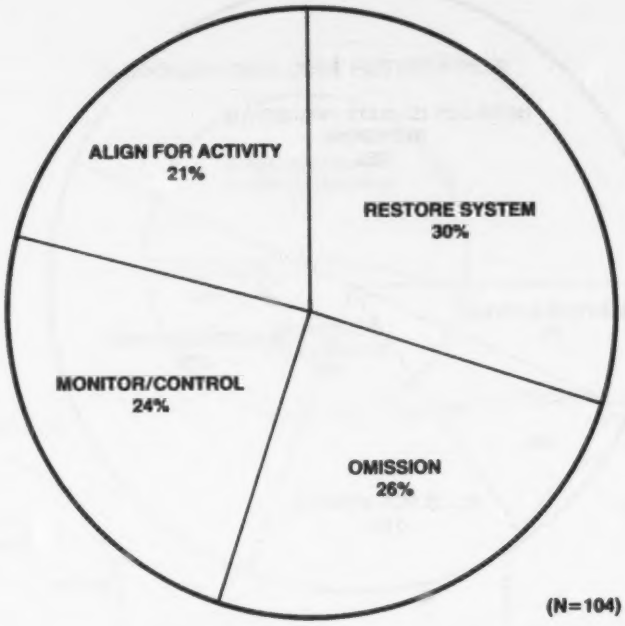

Figure 3.8 Performance Deviations Resulting from Non-Compliance with Procedures

The distribution of the specific kinds of performance deviations resulting from inaccurate procedures is shown in Figure 3.9. It was found that 43% of these LERs were attributed to the use of out-of-date procedures. The procedures did not accurately reflect changes in hardware or specifications (faulty revision processes) or the operators had not been provided with existing up-to-date procedures (faulty document control processes). It is presumed that the remaining 57% of inaccurate procedures resulted from inadequate procedures preparation processes, i.e., faulty analysis, inadequate validation, inadequate editing, etc. Inaccurate procedures attributable to this cause resulted in monitor/control errors (26%), incorrect alignment of a system for an activity such as servicing or repair (15%), and violations of technical specifications (9%). The remaining 7% of LERs reported improper restoration of systems after the service or repair had been completed.

From the foregoing descriptions it is evident that the use of incomplete

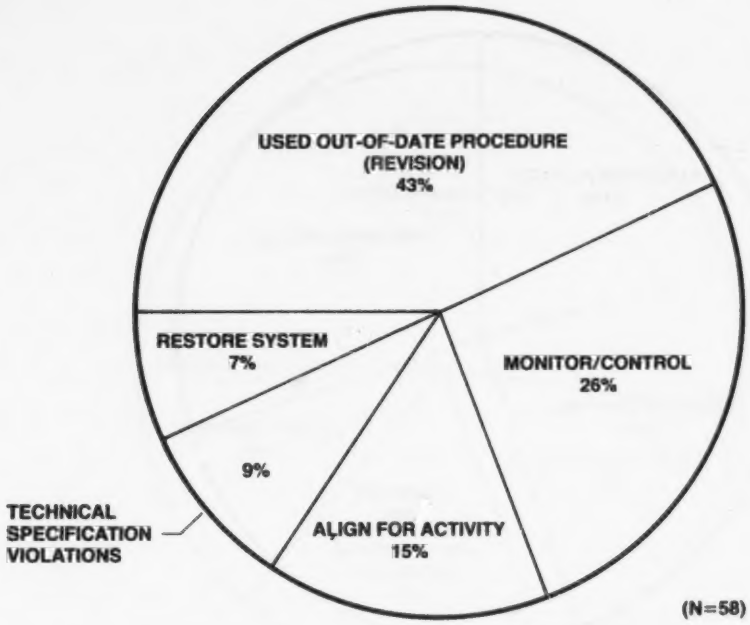

Figure 3.9 Performance Deviations Resulting from Use of Inaccurate Procedures

and inaccurate procedures accounts for a sizeable portion of operator performance deviations. Figure 3.10 presents another view of the effects of inaccurate and incomplete procedures on operator performance. Errors in system alignment and restoration, errors in monitor and control activities, and violations of technical specifications are shown. Forty-seven percent of the alignment errors are the result of inaccurate or incomplete procedures. The remaining 53% of alignment errors result from inadequate use of procedures. Even this latter factor (non-compliance) is amenable to a procedures design solution. If procedures contained provisions for verifying operator actions through inclusion of checklists, signature blocks, etc. many non-compliance errors could be avoided. Seventy-six percent of the monitor/control deviations in activities involving procedures are attributed to incomplete or inaccurate procedures. The remaining 24% are due to non-compliance with procedures. Violations of technical specifications in activities involving the use of procedures appear to be caused solely by incomplete or inaccurate procedures. This source of operator error could be largely eliminated

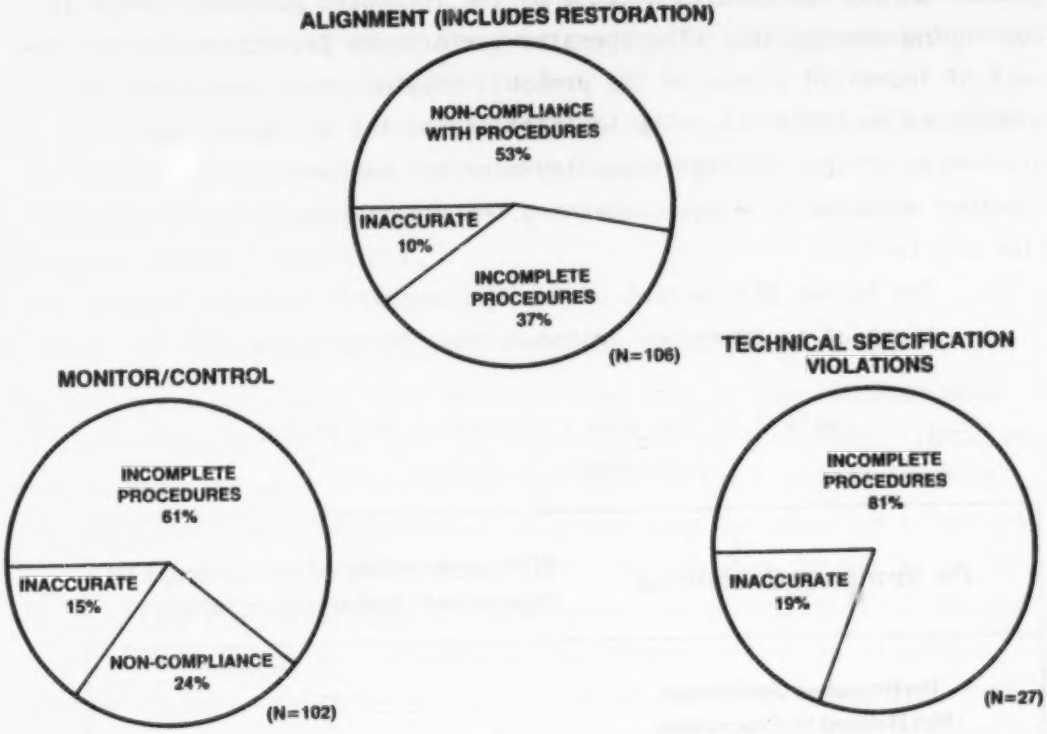

Figure 3.10 Performance Deviations Resulting from Use of Inaccurate and Incomplete Procedures

through improved procedures development and updating processes.

The preceding pages described two groupings of operator performance deviations: 1) those associated with the performance of activities in which procedures do not appear to have been involved, and 2) those that were associated with the use of procedures. The reason that both groups of performance deviations were studied is because both situations apply to operator responses to emergency conditions. That is, operators typically carry out immediate actions without the use of procedures and then use procedures to implement the subsequent actions. Thus, the kinds of performance deviations unrelated to the use of procedures can be expected in the performance of immediate actions; the kinds of performance deviations related to the use of procedures can be expected in the performance of subsequent actions. The probability of their occurrence will be

greater during emergencies because of the increased operator stress accompanying emergencies. The operator performance deviations and the impact of increased stress on the probabilities of their occurrence are summarized in Table 3.3. The implications on the design of emergency procedures of the findings regarding operator performance deviations together with the findings concerning the use of procedures in emergencies are twofold:

1. The format and content of the Symptoms and Immediate Actions sections of an emergency procedure must be designed with the objective

Table 3.3 Operator Performance Deviations Vulnerable to Stress

Performance Deviations	Will probability of occurrence be increased during emergencies?
Performance Deviations Not Related to Procedures	
Inadequate Monitoring/Controlling	Yes
Omissions of Actions	Yes
Incorrect Planning/Decision Making	Yes
Inadequate Communication/Coordination	Yes
Inaccurate Calculating	Yes
Performance Deviations Related to Procedures	
Compliance with Incomplete Procedure	Yes
Non-Compliance with Adequate Procedure	Yes
Compliance with Inaccurate Procedure	Yes
Inadequate Communication/Coordination	Yes
Use of Wrong Procedure	Yes
Misunderstanding of Procedure	Yes

of enhancing the early detection of operator performance deviations that may have occurred during the initial response to an emergency condition.

2. The format and content of the Subsequent Actions section of an emergency procedure must be designed with the objective of preventing the occurrence of procedure-related operator performance deviations.

Characteristics of Emergency Procedures

Ten emergency procedures were obtained from each of four nuclear power plants visited during the data collection phase of the study. These procedures were reviewed with reactor operators at the plants from which they were obtained. In addition, the study team was provided a complete set of emergency procedures from a plant not selected for a visit. It was found that a plant visit was unnecessary to analyze most of the procedural characteristics. Therefore, the larger part of the findings reported below is based on an analysis of 50 emergency procedures from five plants.

Procedures Identification Information

Procedures must be identified so that users can determine the currency and completeness of the copies issued to them. The results of a review of emergency procedures for identification information are summarized in Table 3.4. In three of the plants, each page was identified with the procedure title, procedure number, revision number, and date of issue. In addition, the last page of each procedure was clearly identified. That is, it was marked in one of the following ways: Page___of___; Final Page; Last Page. This identification is particularly important because the last page of a procedure is the one most vulnerable to loss. If it becomes detached from the procedure, this fact must be made immediately apparent to the user. Plant D fails to do this on any of the procedures reviewed and Plant E fails to identify the last page on 70% of the procedures reviewed.

Table 3.4 Procedures Identification Information

Plant	Identifiers		Is the last page identified?
	Title/No.	Revision/Date	
A	All pages	All pages	Yes
B	All pages	All pages	Yes
C	All Pages	All pages	Yes
D	All pages	Title page only	No
E	All pages	20% Title page only 80% All pages	30% Yes 70% No

System Description Information

Figure 3.11 shows the distribution of emergency procedures containing system description information. The provision of this information ranges from a low of 10% of Plant C procedures to a high of 70% of the procedures from Plant E. The descriptive information was a separate section in the front or back of the procedure rather than imbedded within the body of the procedure. These locations do not interfere with on-the-job use of a procedure. All of the plants visited stated that the emergency procedures were used as training aids. Periodic review of the procedures by the operators to refresh their knowledge of the procedures and their application was universal. On the one hand, if the procedures are viewed as training material, the provision of system description information is understandable. It provides context information for performing the actions prescribed by the procedure. On the other hand, its presence in the procedure could encumber the use of a procedure during

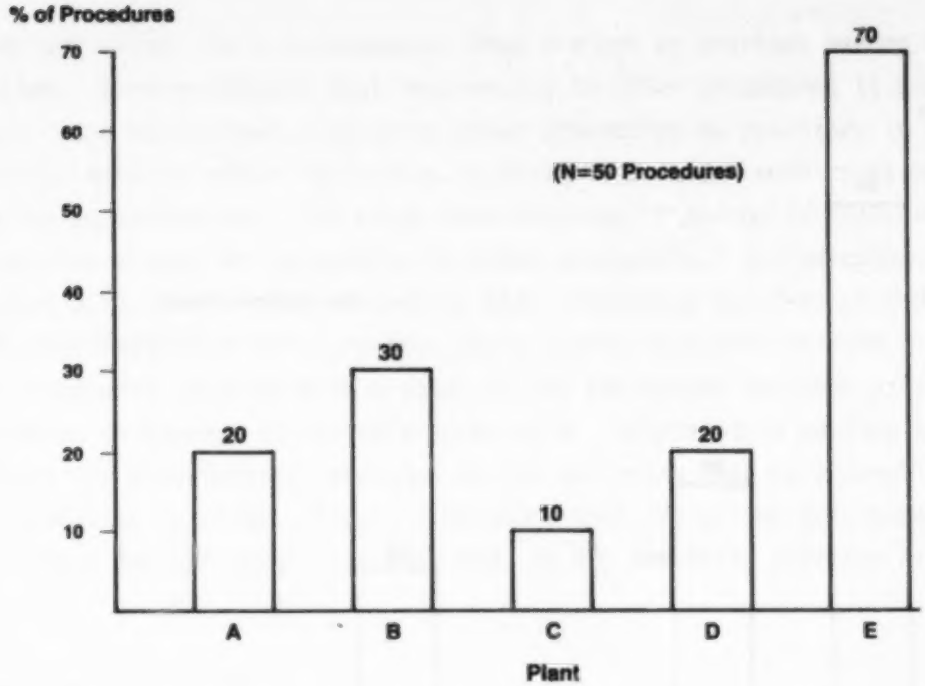

Figure 3.11 Provision of System Description Information in Emergency Procedures

an emergency. As a general rule, it is better to separate training materials from procedures, since each has a different function to perform and can be designed to serve this function better if separate documents are used.

Time Since Last Revision

Each of the emergency procedures reviewed was identified with its revision number and the date of the revision. Figure 3.12 shows the number of years since the last revision for these procedures. It is indicated that 54% of the procedures had been revised within the past year and an additional 24% had been revised within the past two years. It had been two or more years since 22% of the procedures were last revised. All of the emergency procedures are reviewed by each reactor operator at least annually so it is likely that any individual procedure is reviewed in less than one-year intervals. Despite frequent reviews, errors,

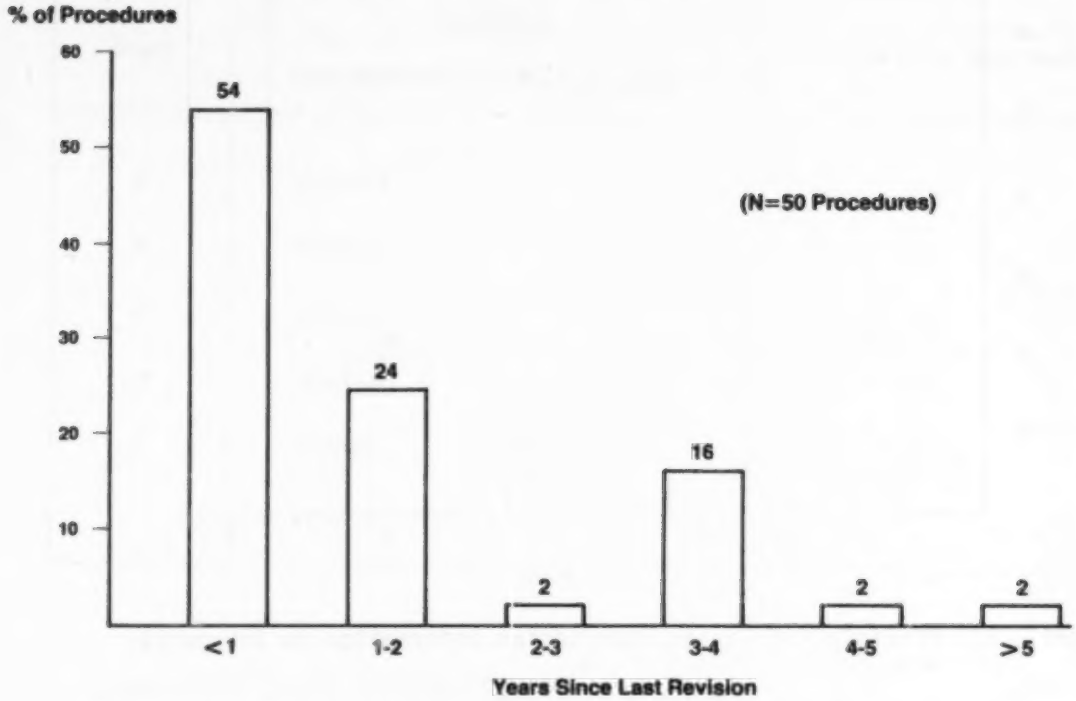

Figure 3.12 Time Since Last Revision of Emergency Procedures

sometimes long-standing, were identified in some of the procedures. These findings suggest that revision dates and review intervals are not necessarily valid indicators of the accuracy or currency of the procedures.

References to Other Procedures

It is a very common practice for the instructions in one procedure to refer users to other procedures for additional instructions concerning some part of the activity. This practice serves to reduce the length and bulk of a procedure. Also, the referenced procedure may contain instructions that experienced persons are expected to know and, consequently, there is no apparent need to repeat it within the procedure. However, it is also known that persons are less likely to obtain information if they must seek it in a document other than the primary one

they are using. As a consequence, they are apt to overlook needed information. Surveys suggest that referencing to other procedures is overused. One of the most common complaints about procedures by operators in nuclear power plants and other facilities is that there is too much cross-referencing in procedures. The study team reviewed 50 emergency procedures from five plants for references to other procedures. As indicated in Figure 3.13, half of the procedures made references to other procedures. The distribution of this practice among plants is fairly uniform. The 25 procedures involved made a total of 150 references to other procedures or an average of six references each. Relying upon persons to obtain six procedures in addition to the one being used to accomplish an operation is risky. Figure 3.14 shows that 37% of the references (or about two per procedure) were made in the Immediate Operator Actions

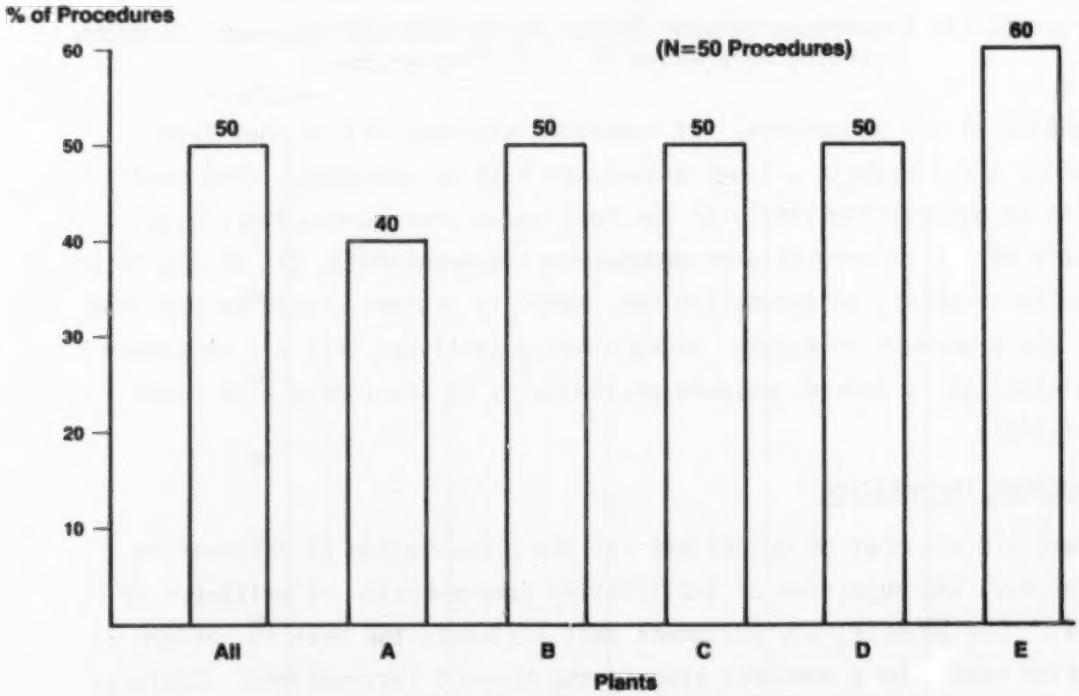

Figure 3.13 Use of References to Other Procedures in Emergency Procedures

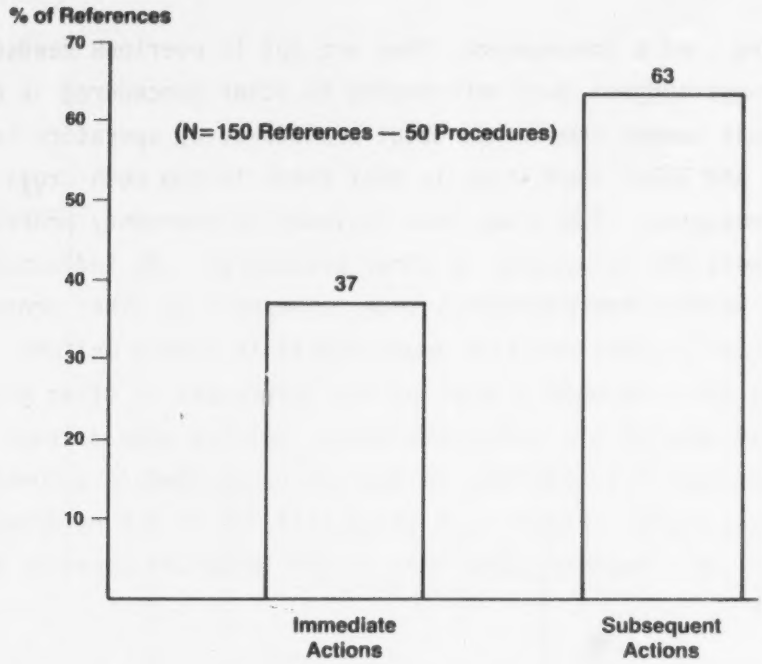

Figure 3.14 Comparison Between Immediate Actions and Subsequent Actions Regarding References to other Procedures

section of the procedures. If operators are expected to know from memory the immediate actions associated with an emergency, they must also be equally familiar with the referenced procedures—or relevant parts of the referenced procedures. As a general rule, all of the information necessary to accomplish the immediate actions should be provided by one procedure to ensure, among other objectives, that all necessary information is indeed reviewed periodically in accordance with plant policies.

Imbedded Information-

There are a number of guidelines for the presentation of information that have the objective of facilitating comprehension of written material. For example, any statement that instructs the user to perform an action should be a numbered step in the body of instructions. Explanatory information that is aimed at assisting the reader to perform a step

effectively should be presented in the form of a note preceding the step(s) to which it refers. This explanatory information should not be expressed in the syntax of an instruction. That is, it should not instruct the user to perform an action. Therefore, if at all possible, it should be written in the passive voice rather than the active voice. In effect, explanations should not be imbedded in instructional steps and, conversely, instructions should not be imbedded in explanatory notes. Violation of this guideline impairs comprehension, an attribute that is particularly vulnerable to the detrimental effects of stress. A total of 89 notes were identified in 50 emergency procedures. The findings, displayed in Figure 3.15, indicate that 61% of the notes contained action instructions. This characteristic can easily result in failures to perform necessary actions because of failures to recognize them, especially when the procedure is used in a stress-inducing situation.

Figure 3.16 presents the results of an analysis of procedural cautions. Fifty cautions were identified in the 50 emergency procedures. As is

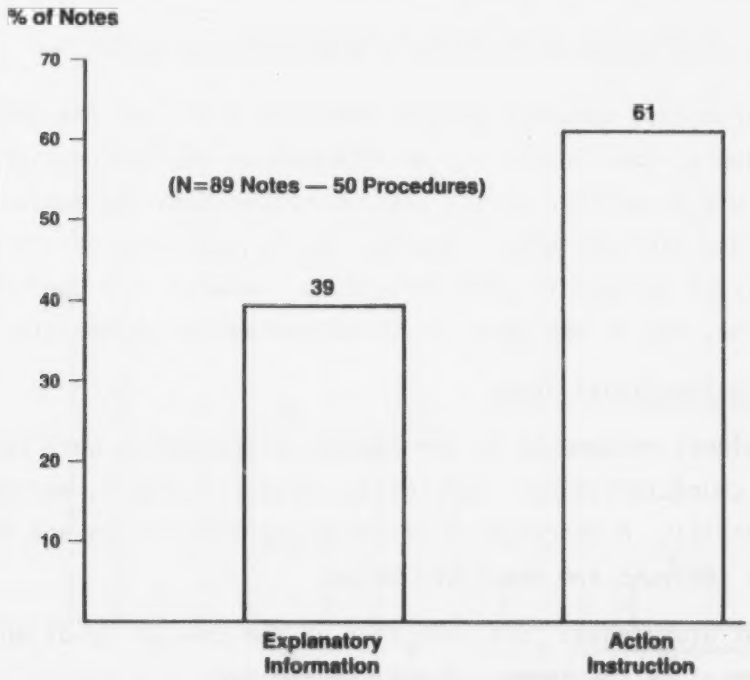

Figure 3.15 Information Contained in Procedural Notes

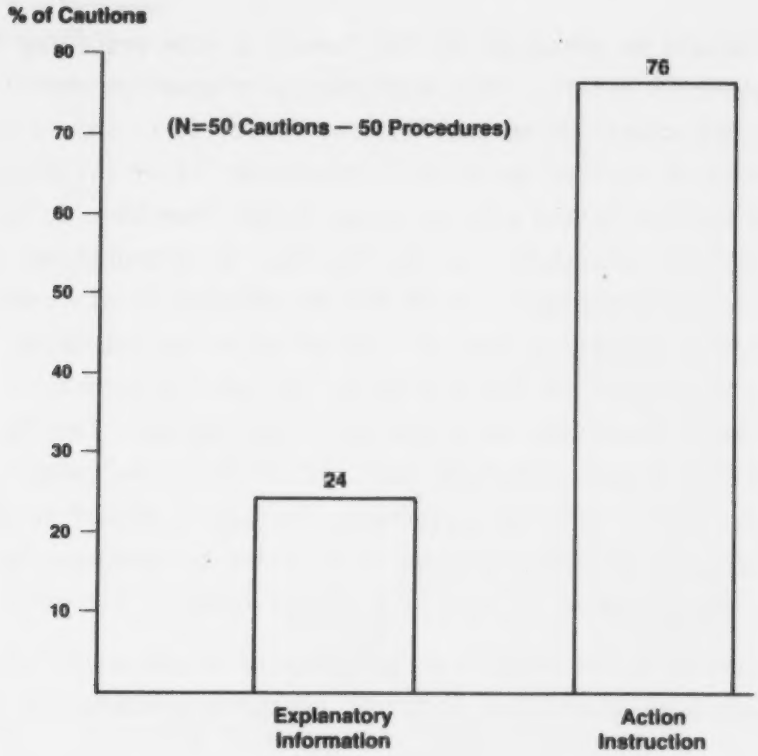

Figure 3.16 Information Contained in Procedural Cautions

the case with notes, cautions should immediately precede the step(s) to which they apply, they should not be imbedded in the instructional step(s), and they should be written in the passive rather than the active voice. In other words, cautions should express the consequences of actions rather than instruct persons to perform actions. However, in conflict with this guideline, 76% of the cautions contained action statements.

Content of Instructional Steps

The instructional statements in the emergency procedures were reviewed for several characteristics: complexity, level of detail, and provision for contingencies. A description of these characteristics and the results of the analysis are described below.

Complexity of Statements: One indicator of the complexity of an instructional statement is the number of actions the user is directed to perform

by the statement. The more actions directed by a statement, the more likely one of them is to be overlooked and, consequently, omitted. Ideally, an instructional statement should contain a single verb followed by the object of the action, e.g., "Open valve", "Observe gauge", "Depress switch", etc. In addition, a statement should contain object identifiers (nomenclature, part numbers) and verb modifiers (slowly open, adjust___ until flow rate is___gpm). In general, a numbered step should consist of one instructional statement or sentence. There are exceptions to this guideline. For example, a numbered step can contain up to three actions if they are related actions, e.g., "4. Open valve PVC-1205. Wait until solution is clear. Close valve." However, to obtain a rough indication of the complexity of instructions, the study team simply counted the number of actions directed by the instructions. The results are presented in Figure 3.17. Thirty-eight percent of the 614 instructional steps reviewed contained only one action verb. Furthermore, 79%

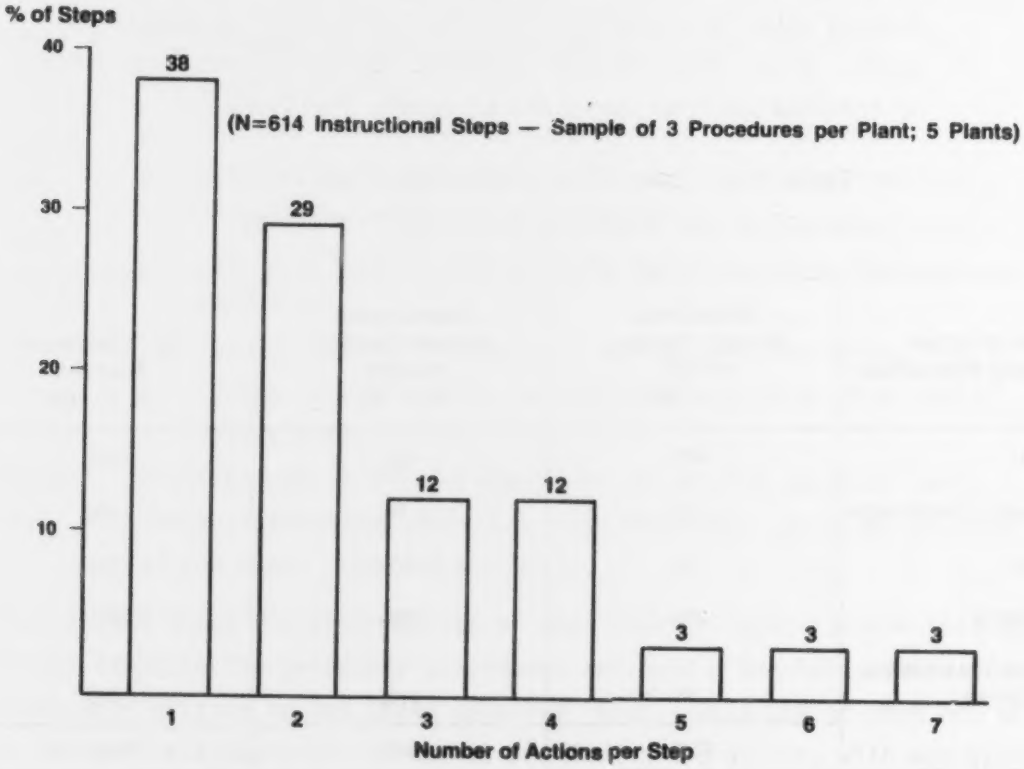

Figure 3.17 Number of Actions Called Out in Instructional Steps

of them contained three or fewer actions. Whether they were related actions or not was not determined. The remaining 21% of instructional steps expressed four or more actions each. These latter instructions risk being too complex to ensure reliable comprehension during stressful conditions. In fact, reliability of comprehension will be greatest for steps that direct only one action, and even then a controlled, consistent, and limited vocabulary is required to achieve highest reliability.

The emergency procedures were further analyzed to determine the kinds of actions that are expressed by the instructions. Table 3.5 lists the results. A total of 1105 actions were identified. They fell into five categories:

1. Verification. For the most part, these instructions directed users to verify that listed symptoms were observed or that specified automatic actions occurred.
2. Communication/Coordination. These instructions dealt with informing other personnel that actions were taken or should be taken. Also, they included requests for assistance from others or information from personnel at remote locations.

Table 3.5 Types of Actions Specified in Instructions in Emergency Operating Procedures

Type of Action Directed by Instruction	Immediate Actions Section N=427 % = 39	Subsequent Actions Section N=678 % = 61	Both Sections N=1105 % = 100
Verification	32%	9%	18%
Communication/Coordination	4%	4%	4%
Calculations	1%	3%	3%
Monitor/Control	58%	73%	68%
Other (general informationai, negative actions)	5%	11%	8%
	100%	100%	100%

3. Calculations. The instructions directed personnel to perform calculations.
4. Monitor/Control. These instructions directed personnel to observe displays and manipulate controls.
5. Other. This category consisted of negative actions, e.g., "Do not open valve____ if ____", and other forms of action statements not easily grouped.

The results are tabulated separately for the Immediate Operator Actions sections of the procedures and the Subsequent Actions sections. The most striking difference between these distributions is the preponderance of verification actions in the Immediate Actions sections.

Level of Detail: An analysis of a sample of instructional steps was performed to determine their level of detail. An instruction was sorted into one of the following three levels of detail:

Level 3. Instructions in this category were the most detailed. They met three criteria:

a. The specific action to be performed was stated.
b. The object on which the action was to be performed was clearly and unambiguously identified, e.g., part number was specified or nomenclature appearing on a label was specified.
c. The conditions or limits of action were specified, e.g., limits were expressed in quantitative rather than qualitative terms.

Level 2. Instructions in this category met two of the above criteria.

Level 1. These instructions were the least detailed. Only one or none of the above criteria was met.

Figure 3.18 shows the distribution of the level of detail of 614 instructional steps in the emergency procedures reviewed. One-half of the steps (51%) were written to the least detailed level. Only 26% of them met all of the criteria described for Level 3. During discussions with operators,

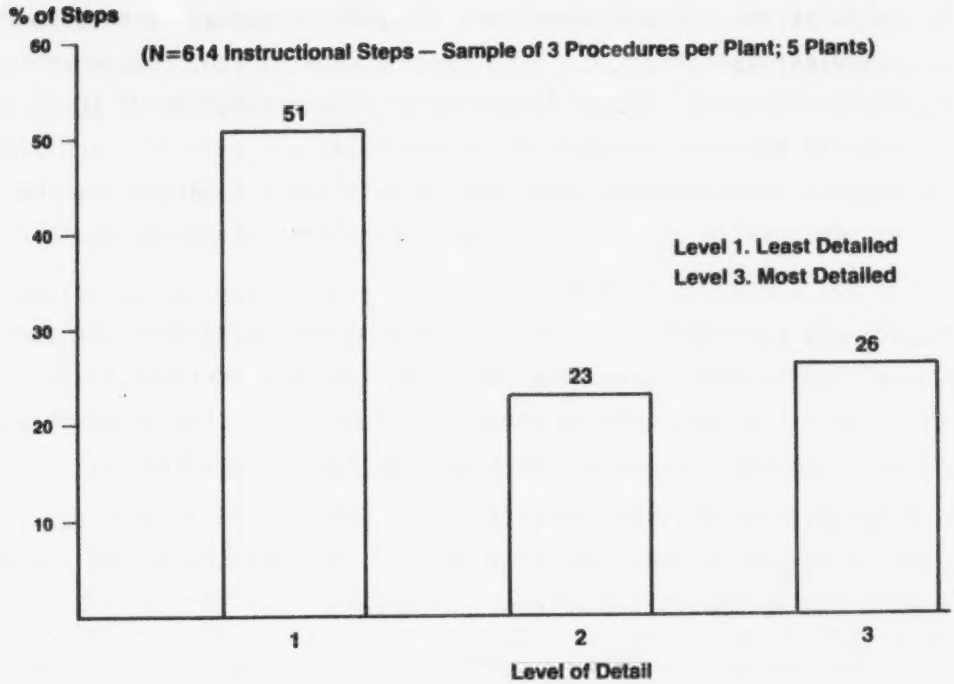

Figure 3.18 Level of Detail in Instructions

it was found that one of the most frequently stated suggestions for improving the procedures was to provide more quantification of limits in instructions. It is ordinarily extremely difficult to define the correct level of detail of information that must be provided to a using group to ensure acceptable reliability in the performance of an activity. Highly experienced personnel will generally need less information than lesser experienced personnel. However, it is extremely important to identify correctly the activities to which their experience applies. For example, an individual might have 10 years of experience driving a car—not one minute of which was performed on icy roads. Likewise, an operator may have years of experience in plant operations but little or no experience in responding to some of the conditions described in emergency procedures. Furthermore, the operator may have limited experience in performing or rehearsing the activities (either specific or generic) prescribed by

emergency procedures. Or extended time periods may have intervened between experiences. These factors plus the detrimental effects of stress on recall and comprehension support the position that more detail should be provided in emergency procedures. The data displayed in Figure 3.19 indicates that considerable improvement can be realized in this area. The data permit a comparison among the plants with respect to the level of detail of instructions in their emergency procedures. There is great variability among them. The procedures from Plant E are the most detailed with 56% of the steps written at Level 3. At the other extreme are Plants C and D with only 1% and 10%, respectively, of the instructions written at this level. In effect, Plant E demonstrates that greater detail can be provided; other data suggest it should be provided.

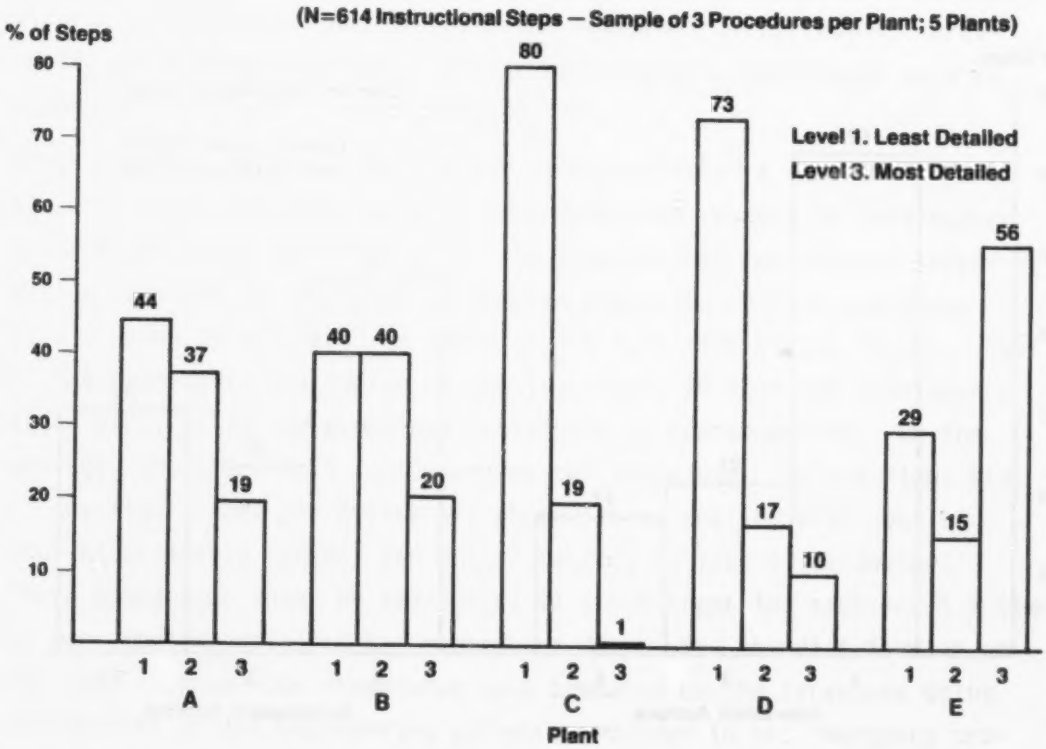

Figure 3.19 Comparison among Plants Regarding Level of Detail of Instructions

One further analysis of level of detail of instructions was performed. A comparison between the Immediate Operator Actions sections and Subsequent Actions sections of emergency procedures was made. As shown in Figure 3.20, only 38% of the instructions in Immediate Actions are written to Level 2 or 3 as opposed to 53% of the Subsequent Action instructions. This finding indicates the relatively great reliance placed upon operator training and memory by licensees for the performance of emergency responses. Because of this emphasis, operator recall of immediate actions should be evaluated periodically.

Contingency Information in Instructions: It is highly unlikely that any two emergency conditions will ever exhibit the same pattern of events, either in terms of their actual occurrence or the sequence of their occurrence. The course of events is dependent upon material, equipment,

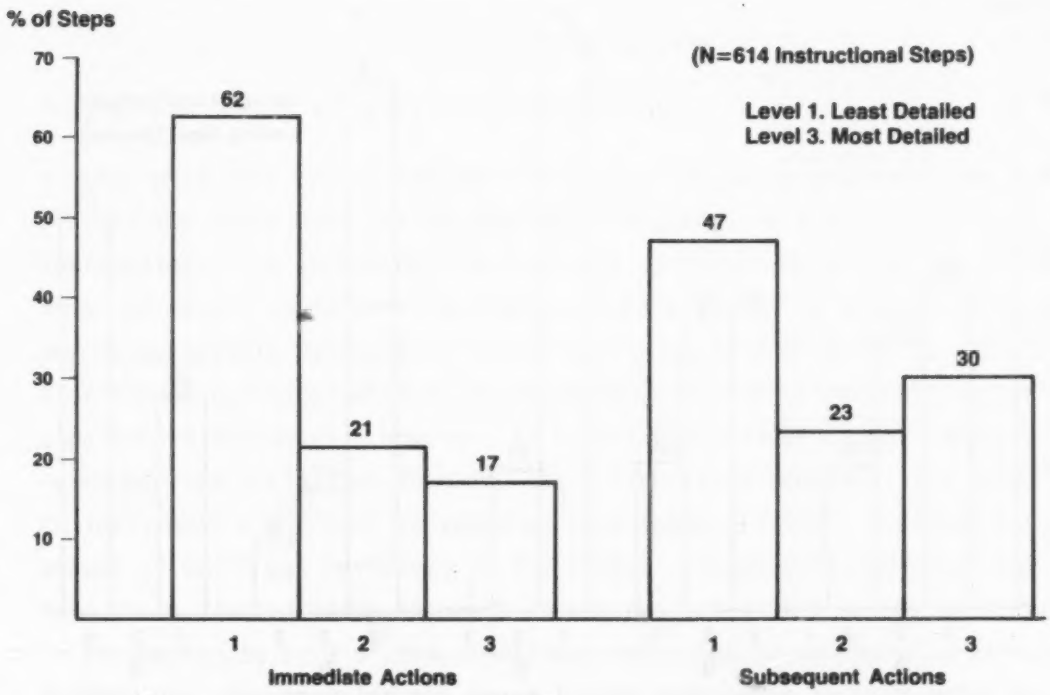

Figure 3.20 Comparison Between Immediate Actions and Subsequent Actions Regarding Level of Detail of Instructions

and operator inputs and these will vary. In recognition of this fact, many of the operators with whom discussions were held questioned the possibility of anticipating and prescribing for such variable events in written procedures.

A review of the procedures disclosed that many of them are written as if an emergency consists of a single series of events and as if operator actions will yield only one set of equipment responses. There is little or no information regarding what actions operators should take if the system does not respond as expected. In other words, the procedures are incomplete with respect to contingency information. This deficiency is predictable when the process used to develop the procedures is examined. In no case did the study team find that a formal analysis process routinely preceded or accompanied the preparation of procedures. Typically, procedures are written by persons, frequently senior operators or supervisors, who are most familiar with the equipment or operation. Ordinarily these people are not familiar with analytic techniques such as contingency analyses, fault analyses, etc.

Figure 3.21 sheds some light on the contribution of a formal analysis process to the completeness of a procedure with respect to contingency information. The distribution of the frequency of contingency information provided in emergency procedures employing current practices (i.e., using no analysis) is shown on the left side of the figure. Four of the procedures considered no contingencies, 10 have one contingency each, etc., up to one procedure containing 13 contingencies. On the average, there are 4.75 contingencies per procedure. On the right side of the figure four procedures are shown, three dealing with loss of coolant accidents (LOCAs) and one pertaining to loss of feedwater. These procedures cover an average of 21.5 contingencies each—or 4.5 times as many contingencies as the procedures comprising the distribution on the left. These four procedures were prepared by the licensees using the results of the engineering analyses provided in the emergency procedure guidelines recently supplied to them by the reactor manufacturers.

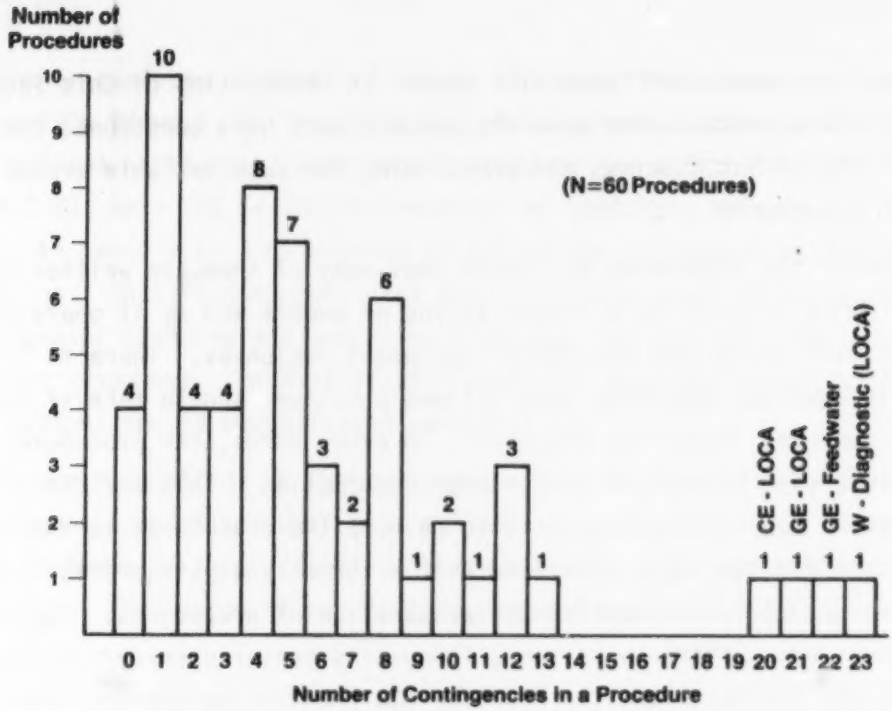

Figure 3.21 Use of Contingency Information in Emergency Procedures

This difference suggests that procedures developed without the use of a formal analysis process are very likely to be incomplete.

Verification of Operator Actions

In the description of operator responses to emergencies, it was stated that in a typical situation, operators observed symptoms, observed the occurrence of automatic actions, and performed immediate actions before obtaining a procedure. The procedure was then used as a guideline to verify the occurrence of symptoms and automatic actions, and to perform subsequent actions. It was suggested that a checklist format would enhance the detection of operator oversights or omissions of necessary actions that might have occurred during this initial response period. A checklist would also leave a record of events for post-emergency analysis.

A complicating factor in emergency situations is that the emergency

responses are seldom performed by a single operator but by a crew of operators. Yet the emergency procedures reviewed contained no provision for coordinating the actions of several operators working together. There are no checklists or other means for recording what actions have been directed and indicating that they have, in fact, been accomplished. Figure 3.22 shows that only 6% of the procedures made any provision for verification by initialing, signing, checking, or entering data. One of the findings from post-TMI-2 studies is that coordination among crew members was deficient. A checklist or other similar provision for verifying operator actions would be a step toward reducing the frequency of operator errors resulting from omitted or improperly executed actions during a period of stress and possible confusion.

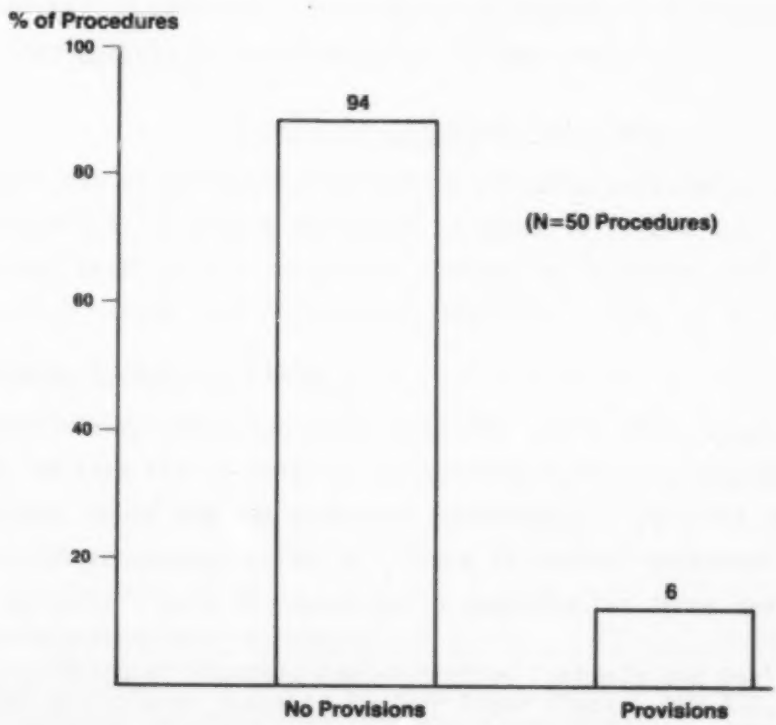

Figure 3.22 Provisions for Verification of Operator Actions in Emergency Procedures

CHAPTER IV

CONSTRUCTION OF CHECKLIST

Sources from which candidate procedures evaluation criteria were drawn consisted of procedures checklists currently in use, evaluation criteria used in studies of procedures by others, procedures design criteria presented in military specifications and available literature, rules and guidelines presented in ANSI N18.7-1976*, and human factors criteria developed by HPT during the current and previous studies. Each source was examined for procedures evaluation criteria that have relevance to quality of job performance. Any criterion pertaining to the format or content of procedures was recorded on index cards. Approximately 80 criteria were developed from this initial review. This group was then screened for redundant items and items that did not appear to have significant impact on the quality of operator responses to emergency conditions. The remaining procedures evaluation criteria were then entered on worksheets for further analysis.

Development of Checklist Items

The full set of procedures evaluation criteria worksheets is presented in Appendix A. A sample worksheet is shown in Figure 4.1. The major worksheet headings are Procedures Evaluation Criteria, ANSI N18.7-1976*, Evaluation Method, and Performance Deviation. Each is described below.

Procedures Evaluation Criteria

The preliminary checklist items were entered in this column. To be entered, an item had to refer to a characteristic of a procedure which, if deficient, could degrade personnel performance. Item #25 in Figure 4.1 deals with acceptance criteria. There is general agreement that acceptance criteria should be expressed in quantitative terms whenever possible.

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*American National Standard Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants, ANS-3.2, ANSI N18.7-1976, Revision of N18.7-1972, American Nuclear Society, Hinsdale, IL.

Procedures Evaluation Criteria	ANSI N18.7-1976	Eval. Meth.			Performance Deviation									
		Doc. Rev.	Walk-Thru. Inspector	Walk-Thru. Operator	Monitor/Control	Omissions	Planning/Decision	Comm./Coord.	Calculating	Incomplete Proc.	Non-Compliance	Inaccurate Proc.	Wrong Procedure	Comprehension
23. Are explanations separate and easily discriminable in appearance from instructional steps? For example, are they enclosed in boxes, typed in bold face letters, headed with the word NOTE, etc?	O	✓												✓
24. Do explanatory notes avoid the use of action statements? (Statements directing personnel to perform actions must not be imbedded in explanatory notes.)	O	✓			✓	✓					✓			✓
25. Are acceptance criteria and limits expressed in quantitative terms when possible?	5.3, 5.3.2	✓			✓							✓		✓
26. Are quantitative acceptance criteria and limits expressed as ranges as opposed to point values?	O	✓												✓
27. Are the acceptance criteria and limits compatible with the limits stated in requirements documents?	O	✓										✓		
28. Does the procedure provide instructions for all reasonable contingencies? For example, if equipment is operating outside the range specified by the procedure, is the operator instructed what action to take?	5.3.3	✓			✓	✓	✓			✓				
29. Are the contingencies provided for in the procedure based upon engineering failure analyses?	O	✓								✓		✓		
30. Are contingency instructions expressed so that the contingency precedes the action statement? For example, a contingency instruction should be written "If____, do____", not "Do____, if____."	O	✓			✓									✓
31. Are contingency instructions easy to understand? For example, if three or more contingencies must be met before action is directed, the contingencies should be listed separately from the action statement and ahead of the action statement.	O	✓			✓	✓								✓
32. If calculations are required, is space provided in the procedure to perform the computations and to record the results?	O	✓			✓		✓		✓					
33. Are computations based on technically accurate, complete and up-to-date formulas?	O	✓							✓			✓		
34. Are graphs, charts, and tables adequate for readability and interpolation or extraction of values?	O	✓			✓	✓	✓		✓		✓			✓
35. Evaluate the complexity of the instructions by determining the average number of actions per step that the user is directed to perform. Use all steps in calculating the average. Is the average number of actions per step 2.0 or less?	O	✓				✓								✓

Figure 4.1 Worksheet for Developing Checklist Items

This characteristic permits decisions to be made on the basis of measurable quantities rather than subjective judgments. In many cases, subjective judgments might vary too greatly among persons, or within one person from time to time (particularly in view of stress-induced perceptual distortions), to permit consistently acceptable decisions and resultant actions.

ANSI N18.7-1976

One version or another of this document is used by many licensees as a guideline for the content and application of procedures. It provides both general and specific criteria for procedural format and content. For each procedures evaluation criterion entered on the worksheet, ANSI N18.7-1976 was examined to determine if it appeared to support the item by specific statement or, at a minimum, by reasonable interpretation of intent. If it did, the number of the relevant paragraph was recorded in this column. If it did not, a zero (0) was entered. This information can be used for determining what additional enforcement tools are needed to increase the effectiveness of the procedures evaluation process.

Evaluation Method

Each item was reviewed to determine the most effective method for evaluating the procedure characteristic contained in the item. Three methods for performing an evaluation were considered: Document Review, Inspector Walk-Through, and Operator Walk-Through. They are described in the following paragraphs.

1. Document Review: This method consists of obtaining the procedures of interest and their related documents and evaluating them with respect to the criteria. Typically, related documents consist of 1) drawings, procedures, schematics, etc. specifically referenced by the procedure, and 2) technical specifications, Final Safety Analysis Reports (FSARs), and other basic requirements documents which might affect the content of the procedures. In some cases, it might also be necessary to examine corporate policies and station directives having an impact on procedures

contents. For example, valve alignment, logging, and tagging activities might be described in a directive rather than a procedure. The inspector should review the documents describing these processes in order to determine whether or not any of this information should be contained in the emergency procedure itself rather than in a less immediately accessible document.

These documents, in combination, comprise the information system affecting the content of procedures and, consequently, the performance of emergency responses. If an inspector cannot evaluate a procedures characteristic from the available documents alone when a document review has been specified, it can be assumed that the information system is deficient with respect to completeness or with respect to organization. Either deficiency will affect the quality of procedural content adversely.

2. Walk-Through, Inspector: Some evaluations, such as determining the correspondence between equipment nomenclature or identification numbers used in a procedure and the nomenclature or numbers actually displayed on equipment, can be performed by the inspector only by walking through the facility with the procedure in hand and comparing the two. During the walk-through it might be desired to make selected human factors observations of the work environment, the facility layout, and the equipment, all of which bear upon the effectiveness and safety of personnel performance. For example, the inspector might wish to assess the readability of legends and displays from the perspective of the person performing the procedure. Also, distances between operator stations and control positions could be noted to evaluate the efficiency of task sequences and their compatibility with job requirements, such as the performance of time-critical tasks.

All of these evaluations can be made during the walk-through of a procedure with an operator, as described below. Because there would be very little increase in time by adding them to that process, they have been incorporated into the operator walk-through evaluation on the checklist itself.

3. Walk-Through, Operator: Unlike the preceding methods, the performance of this evaluation requires the direct support of licensee personnel. The objective of this method is to judge whether the amount and kind of information provided by the procedure is complete with respect to the information needs of the user. That is, the inspector seeks to evaluate the adequacy of the "level of detail" of the procedure. This attribute of a procedure is the most difficult of all procedural characteristics to evaluate. Judgments of adequacy of level of detail are based on assumptions about the qualifications of the personnel for whom the procedure is provided. Such assumptions are often tenuous at best because of the wide differences between groups of operators with respect to training for emergencies and the relatively unknown effects of these differences in training.

Partial evidence of the completeness of a procedure can be obtained with the assistance of an experienced operator. The operator should perform a walk-through of the procedure, simulating the actions specified in the instructions. During this process, the completeness of the symptoms and automatic actions sections of the procedure should be evaluated insofar as possible by means of discussions with the operator. An emergency procedure must be complete with respect to the symptoms and automatic actions that can be associated with the event for which the procedure was prepared. Any omissions should be corrected.

The operator walk-through can also contribute to a partial evaluation of the completeness of instructions concerning immediate operator actions. If the operator is observed performing immediate actions that are not prescribed by the procedure, a judgment must be made regarding the criticality of the action toward stabilizing the event. If the action is judged critical, it should be included in the procedure. The fact that the action was performed without a written instruction during the procedure evaluation process is no guarantee that it will be recalled equally well during an emergency.

The technical accuracy of the procedure must be ascertained for the most

part by means of engineering analyses. The walk-through can address only a limited number of procedure characteristics for accuracy. For example, the correspondence between nomenclature on the equipment and in the procedures can be evaluated.

Performance Deviation

The analysis of LERs disclosed 10 major categories of performance deviations associated with reactor operator activities. They were entered on the worksheet as column headings. Each procedures evaluation criterion was reviewed with regard to its relationship to the performance deviation categories. To be retained for inclusion in the final checklist, an item had to address one or more kinds of performance deviations. The 10 kinds of performance deviations in the worksheet are:

1. Monitoring/Controlling:

   Monitoring. Failure to respond to alarm, misinterpretation of indications, failure to maintain proper control of levels, pressure, rates, etc.

   Controlling.

   Incorrect alignment. System not properly aligned for action contemplated—usually clearly stated as "misalignment" in LER.

   Incorrect manipulation. Control moved in wrong direction, set in incorrect position, improper sequence or timing.

   Incorrect identification. LER clearly states the item was misidentified as to unit and/or identification number.

   Wrong control. Activated wrong control due to close proximity of controls or similar appearance (no mention of identification number).

   Accidental actuation. Unintentional actuation. Activated while cleaning, shoulder brushed against control, etc.

2. Omissions:

   Failed to restore. System not restored after a previous action. Generally reported as an item "found" in wrong position.

   Omitted action. An important action was omitted during the performance of an activity.

Omitted procedure. Entire procedure was overlooked and the required activity did not take place, i.e., "follow on" not performed.

3. Planning/Decision Making:

Incorrect decision. Operator decided on course of action based on what information he had and decision led to LER.

Unaware of status. Operator stated that he was unaware of system status or the full consequence of the action undertaken.

Misinterpreted Technical Specification. Operator stated that his actions were based on what he considered to be the correct meaning of the Technical Specification.

Incorrect tagging. Valves designated on tags were not correct for the alignment required or wrong valves were tagged.

4. Communication/Coordination:

Misunderstanding of verbal or written communication, initiation of unauthorized actions, incomplete transmission of information at shift changes. Did not log data properly.

5. Calculating:

Errors in performing calculations and extrapolation of data.

6. Incomplete Procedure:

The instructions in a procedure were incomplete, i.e., steps were missing or the step lacked sufficient information to assure a proper response.

7. Non-Compliance:

Unauthorized action. A procedure was available but not used or followed. An action not in the procedure was performed or a step was performed out of the sequence specified in the procedure. Steps were not performed.

Incorrect action. A procedure was used but an error was committed in the performance of a step.

8. Inaccurate Procedure:

The instructions in a procedure were incorrect, e.g., wrong values, improper identification of components, etc.

9. Wrong Procedure;

Operator misidentified the procedure or diagnosed the event incorrectly.

10. Comprehension:

Operator misinterpreted an instruction in the procedure.

The first five categories of performance deviations resulted from operator activities in which the presence of a procedure was not reported. However, these performance deviations must be considered in the design of the procedures evaluation checklist because the immediate operator actions are typically performed without the use of a procedure. An emergency procedure must be designed to aid the operators to detect these five kinds of performance deviations in the event they occur and before they impact risk. The procedures evaluation checklist permits the inspector to determine whether or not the procedure has the necessary "error detection" characteristics.

The remaining performance deviations resulted from activities in which procedures were used. The checklist items addressing these performance deviations enable the inspector to identify procedure characteristics that are directed towards preventing the occurrence of these performance deviations.

Before the procedures evaluation criteria were entered on the checklist they were re-written as necessary so that they could be answered Yes, No, or Not Applicable. A Yes indicates that the procedure possesses a desirable attribute, No means it lacks the attribute, and Not Applicable means it is not relevant to the attribute. For example, a procedure could not be evaluated regarding the accuracy with which it identified referenced documents if it did not refer to other documents. The checklist items were then assigned ratings in accordance with the concept described in the following section.

Weighting of Checklist Items

The final task in constructing the checklist was to assign a weight to

each checklist item. The weight is intended to indicate the impact of the characteristic referred to in the item on the quality of human performance. In all cases, if a procedure is deficient with respect to the characteristic referred to by an item, a performance deviation is more likely to occur than if the procedure possesses the characteristic. However, the absence of some procedural characteristics is more likely to result in performance deviations than the absence of others. It was therefore necessary to develop a method of rating the checklist items that would indicate to the procedure evaluator the relative importance of the characteristic stated in the item.

Quantitative data concerning the relationships between procedures characteristics and performance deviations are extremely limited. Even the findings from this study pertaining to the frequencies of performance deviations cannot be converted into probabilities of performance deviations, because there are no data showing the frequencies with which activities are performed. For example, although the frequency of monitor/control performance deviations is high when compared to the frequencies of other performance deviations, the probability of their occurrence might be infinitesmal when compared to the total number of monitor/control actions that are performed. Therefore, the frequency data do not necessarily indicate the relative probabilities of occurrence of the performance deviations. Because of the preceding factors, it was decided to avoid using frequencies of performance deviations to weight checklist items directly. They were used for guidance only.

Dr. Alan Swain of Sandia National Laboratories has developed a five-category rating scale for ergonomic deviations. It is used for evaluating equipment characteristics with respect to their impact on quality of operator performance, in terms of likelihood of error, under various conditions of stress. The scaling approach is equally applicable to developing a rating scale for evaluating procedure characteristics with respect to their impact on the quality of operator performance. Using this scaling approach, the investigators developed a

four-category scale for rating procedural deficiencies. The rating scale is presented in Table 4.1.

Each checklist item was rated A, B, C, or D. The rating indicates to the inspector the relative importance, in terms of contributing to performance deviations, of a procedural deficiency of the characteristic expressed in the item. The ratings of the checklist items are provided in the checklist itself.

Table 4.1 Rating of Checklist Items

	Probability of Performance Deviation Under:		
Rating	Low Stress*	Moderate Stress*	High Stress*
A	Moderate	High	High
B	Moderate	Moderate	High
C	Low	Moderate	Moderate
D	Low	Low	Moderate

*These terms are defined with descriptions and examples in Swain, A.D. and Guttmann, H.E., Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, NUREG/CR-1278, United States Nuclear Regulatory Commission, Washington, D.C., October 1980.

The ratings in Table 4.1 can be interpreted as follows:

A—Errors are likely to occur during low stress (normal) conditions and will be made frequently under moderate and high stress conditions.

B— Errors are likely to occur during low and moderate stress conditions and will occur frequently under high stress.

C— Errors are not very likely under low stress but could occur readily under moderate and high stress.

D— Errors are not very likely to occur under low and moderate stress but could readily occur during high stress.

As noted, each checklist item is rated to convey to the inspector its relative value in reducing the frequency of performance deviations reported in LERs. These ratings, integrated with an inspector's own judgment of the level of stress likely to be associated with a particular emergency condition and knowledge of the consequences of error associated with the performance of a specific procedure or action, will aid the inspector to assess the importance of correcting a particular procedural deficiency. The Emergency Procedure Evaluation Checklist is presented in Appendix B. Appendix C provides explanations of the individual checklist items.

CHAPTER V

APPLICATION OF CHECKLIST

I & E inspectors are currently responsible for evaluating plant operating procedures, including maintenance, test, calibration, and normal operating procedures as well as the emergency procedures. Furthermore, the evaluation of procedures is only one of many tasks that an inspector must perform. The checklist is intended to be used as an aid to identify procedural deficiencies that can lead to human performance deviations or errors. To enable an inspector to identify all such procedural deficiencies whould require a very lengthy and cumbersome checklist. The task of evaluating a procedure with such a checklist would be an extremely time-consuming process. Indeed, the most thorough-going method for evaluating procedures would be to evaluate the compliance of procedures with a comprehensive procedures specification.

A checklist, on the other hand, can be thought of as a screening device which should enable an inspector to identify the most important procedural deficiencies in terms of their impact on the quality of human performance in the shortest possible time. If one assumes that the consequences of performance deviations are the same for each deviation, the more deviations that can be prevented per unit investment of inspector time, the greater the safety efficiency of the inspection process. With this philosophy in mind, the study team attempted to construct a checklist that was as short as feasible to enable an inspector to identify the procedural deficiencies that, if eliminated, would significantly reduce the frequency and impact of the kinds of performance deviations that reactor operators have actually made. To further assist the inspectors to use their time efficiently, each checklist item has been rated according to its probable impact upon the quality of operator performance. This feature enables the inspectors to make selective use of the checklist.

Two procedures evaluation processes have been described: 1) the Document

Review, consisting of a desk-top review of the emergency procedures and related documents, and 2) Operator Walk-Through, consisting of observing an experienced operator simulate the tasks prescribed by the procedure. A partial evaluation of the completeness of the information pertaining to immediate operator actions can be made by observing the operator walk-through. In addition, a partial assessment of the completeness of the symptoms and automatic actions information can be made by questioning the operator. The appropriate evaluation process to use is identified for each item on the checklist.

CHAPTER VI

CONCLUDING REMARKS

The checklist can be applied to serve either or both of two distinctly different purposes. They are:

1. to identify deficiencies in a sample of procedures with the objecttive of correcting the deficiencies in that specific sample of procedures, and/or
2. to identify deficiencies in a sample of procedures with the objective of correcting the process which produced the deficient procedures.

In the first case, the inspector is basically performing the function of an editor, and, as a result, the impact of the inspection process will be confined for the most part to the individual procedures being evaluated. The rate at which existing procedures are modified and new procedures are prepared far outpaces the rate at which they can be evaluated by I & E inspectors. Therefore, if only changes in identified deficiencies are sought, the objective of improving the effectiveness and safety efficiency of the I & E inspection process will not be attained.

In the second case, the impact of the inspector on the quality of procedures will be maximized. Here, the procedures are viewed primarily as indicators of the quality of the procedures development process. Although the inspector should also try to have the specific procedures corrected, the main objective of the evaluation is to determine the quality of the procedures development process. If the samples of procedures exhibit particular deficiencies in common with each other, a change in the process used to prepare or revise the procedures, or a change in the specifications governing the format or content of the procedures is called for. This kind of corrective action, coupled with periodic inspections, will effectively improve the quality of all of the emergency procedures, rather than just the procedures selected for

review. If the checklist is used in this manner, the objective of improving the effectiveness and safety efficiency of the I & E inspection process will be realized.

APPENDIX A

WORKSHEETS FOR DEVELOPING CHECKLIST ITEMS

Procedures Evaluation Criteria	ANSI N18.7-1976	Eval. Meth.			Performance Deviation								
		Doc. Rev.	Walk-Thru, Inspector	Walk-Thru, Operator	Monitor/Control	Omissions	Planning/Decision	Comm./Coord.	Calculating	Incomplete Proc.	Non-Compliance	Inaccurate Proc.	Wrong Procedure	Comprehension
1. Does the title describe the emergency for which the procedure is provided?	5.3.4.1	✓											✓	✓
2. Does each page provide the following identification information?														
1. Procedure number and/or title	0	✓				✓				✓		✓		
2. Date of issue														
3. Revision number														
4. Page number														
3. Is the last page of the procedure clearly identifiable by marking, e.g., Page___of___; Final Page?	0	✓				✓				✓				
4. If this is a temporary procedure, is it clearly marked with the expiration date?	0	✓											✓	
5. Do the immediate operator actions avoid referencing operators to other procedures for instructions?	0	✓								✓	✓			
6. Are the titles and numbers of all referenced documents identified correctly? (If the procedure refers personnel to other procedures for instructional information each reference must be evaluated as an independent procedure starting with Item #1 of the checklist.)	5.3.2	✓										✓		
7. If this is a multiple unit site, does the procedure refer to one unit only?	0	✓												✓
8. If more than one person is required to perform the procedure, is the procedure written to one 'primary' user? That is, is it clear from the way that instructions are written that one person is responsible for coordinating the activity?	0	✓						✓			✓			✓
9. When communication between personnel is required, does the procedure specify how and to whom?	0	✓						✓			✓			✓
10. Does the procedure contain provisions for coordinating the activities of others? For example, is there a checklist for recording that someone has been directed to take an action and for recording that the action has been completed?	5.3.2	✓				✓	✓	✓			✓			
11. Does the procedure contain provisions for verifying that symptoms associated with the emergency were actually observed? For example, is there a checklist for recording that a symptom was observed?	5.3.2	✓			✓	✓	✓				✓			

Procedures Evaluation Criteria	ANSI N18.7-1976	Eval. Meth.			Performance Deviation									
		Doc. Rev.	Walk-Thru, Inspector	Walk-Thru, Operator	Monitor/Control	Omissions	Planning/Decision	Comm./Coord.	Calculating	Incomplete Proc.	Non-Compliance	Inaccurate Proc.	Wrong Procedure	Comprehension
12. Does the procedure contain provisions for verifying that automatic actions associated with the emergency were actually observed? For example, is there a checklist for recording that an automatic action was observed?	5.3.2	✓			✓	✓	✓				✓			
13. Does the procedure contain provisions for verifying that critical immediate operator actions performed from memory were actually performed? For example, is there a checklist for recording that an immediate action was performed?	5.3.2	✓			✓	✓	✓				✓			
14. Are the instructions typed in both upper and lower case letters (as conventionally used) as opposed to all upper case letters?	0	✓												✓
15. Are instructions written in short, concise, identifiable steps as opposed to multi-step paragraphs?	0	✓				✓								✓
16. Are steps that must be performed in a fixed sequence clearly identified to the user? For example are the steps marked with asterisks or is the sequence marked "Mandatory" or "Step-by-Step", etc.?	5.2.2	✓									✓			
17. If a step contains more than two objects of action, are they listed rather than imbedded in the sentence? For example, if an operator is directed to close three or more valves, they should be listed rather than strung out in a sentence.	0	✓				✓								✓
18. If cautions are applicable to the performance of specific steps or series of steps, are they placed immediately ahead of the step(s) to which they apply?	0	✓			✓	✓					✓			✓
19. Are cautions separate and easily discriminable in appearance from instructional steps? For example, are they enclosed in boxes, typed in bold face letters, headed with the word CAUTION, etc.?	0	✓												✓
20. Do cautions avoid the use of action statements? (Statements directing personnel to perform actions must not be imbedded in cautions. Cautions should be expressed in the passive voice.)	0	✓				✓					✓			✓
21. Are cautions provided to inform personnel when displays are based on secondary sensing modes?	0	✓			✓									✓
22. If explanations, i.e., notes, are applicable to the performance of specific steps or series of steps, are they placed immediately ahead of the step(s) to which they apply?	0	✓			✓	✓					✓			✓

Procedures Evaluation Criteria	ANSI N18.7-1976	Eval. Meth.			Performance Deviation									
		Doc. Rev.	Walk-Thru, Inspector	Walk-Thru, Operator	Monitor/Control	Omissions	Planning/Decision	Comm./Coord.	Calculating	Incomplete Proc.	Non-Compliance	Inaccurate Proc.	Wrong Procedure	Comprehension
23. Are explanations separate and easily discriminable in appearance from instructional steps? For example, are they enclosed in boxes, typed in bold face letters, headed with the word NOTE, etc?	O	✓												✓
24. Do explanatory notes avoid the use of action statements? (Statements directing personnel to perform actions must not be imbedded in explanatory notes.)	O	✓			✓	✓					✓			✓
25. Are acceptance criteria and limits expressed in quantitative terms when possible?	5.3, 5.3.2	✓			✓							✓		✓
26. Are quantitative acceptance criteria and limits expressed as ranges as opposed to point values?	O	✓												✓
27. Are the acceptance criteria and limits compatible with the limits stated in requirements documents?	O	✓										✓		
28. Does the procedure provide instructions for all reasonable contingencies? For example, if equipment is operating outside the range specified by the procedure, is the operator instructed what action to take?	5.3.3	✓			✓	✓	✓			✓				
29. Are the contingencies provided for in the procedure based upon engineering failure analyses?	O	✓								✓		✓		
30. Are contingency instructions expressed so that the contingency precedes the action statement? For example, a contingency instruction should be written "If____, do____", not "Do____, if____."	O	✓			✓									✓
31. Are contingency instructions easy to understand? For example, if three or more contingencies must be met before action is directed, the contingencies should be listed separately from the action statement and ahead of the action statement.	O	✓			✓	✓								✓
32. If calculations are required, is space provided in the procedure to perform the computations and to record the results?	O	✓			✓		✓		✓					
33. Are computations based on technically accurate, complete and up-to-date formulas?	O	✓							✓			✓		
34. Are graphs, charts, and tables adequate for readability and interpolation or extraction of values?	O	✓			✓	✓	✓		✓		✓			✓
35. Evaluate the complexity of the instructions by determining the average number of actions per step that the user is directed to perform. Use all steps in calculating the average. Is the average number of actions per step 1.5 or less?	O	✓				✓								✓

Procedures Evaluation Criteria	ANSI N18.7-1976	Eval. Meth.			Performance Deviation									
		Doc. Rev.	Walk-Thru, Inspector	Walk-Thru, Operator	Monitor/Control	Omissions	Planning/Decision	Comm./Coord.	Calculating	Incomplete Proc.	Non-Compliance	Inaccurate Proc.	Wrong Procedure	Comprehension
36. Evaluate the level of specificity of the instructions by determining the percent of steps in the procedure that meet all of the following criteria. Use all steps in calculating the percent. 1. The action to be taken is specifically identified (open, close, rotate, etc.). 2. Limits are expressed quantitatively, e.g., 2 turns, 80 (75-85) in. lbs. 3. Equipment and parts are identified completely (HPCI-MO-17, etc.). Do 90% of the steps meet the above criteria?	5.3.2	✓			✓					✓	✓			✓
37. Do the alignment instructions in the procedure meet all of the following criteria? 1. Each item requiring alignment is individually specified. (It is not acceptable to refer personnel to previous steps.) 2. Each item is identified with a unique number or nomenclature. 3. The position in which the item is to be placed is specified. 4. The position in which the item is placed is verified.	5.3.2	✓			✓	✓				✓	✓			✓
38. If the procedure specifies an action that must be repeated at periodic intervals, does it contain provisions for flagging the operator to perform the action? For example, if an action must be repeated every 15 minutes, are there spaces to record the times at which the action must be performed?	0	✓			✓	✓	✓	✓			✓			
39. Does the procedure identify all likely symptoms or combinations of symptoms associated with the emergency? (If an engineering analysis is not available determine whether the operator can describe symptoms or combinations not identified by the procedure.)	5.3.9.1			✓						✓				
40. Does the procedure specify automatic actions associated with the emergency adequately? (Determine whether the operator can describe automatic actions not specified by the procedure.)	5.3.9.1			✓						✓				

Procedures Evaluation Criteria	ANSI N18.7-1976	Eval. Meth.			Performance Deviation									
		Doc. Rev.	Walk-Thru, Inspector	Walk-Thru, Operator	Monitor/Control	Omissions	Planning/Decision	Comm./Coord.	Calculating	Incomplete Proc.	Non-Compliance	Inaccurate Proc.	Wrong Procedure	Comprehension
41. Does the procedure specify all critical actions required to respond to the emergency? (Observe whether the operator performs critical actions not specified by the procedure.)	5.3.9.1			✓						✓				
42. If the procedure contains sequence-critical actions, is the sequence specified by the procedure correct? (Observe whether the operator performs sequence-critical actions in the sequence specified.)	O			✓								✓		
43. Does the procedure allow enough time to perform time-critical actions? (Observe whether the operator can perform time-critical actions in the time allowed, i.e., by equipment response, distances involved, etc.)	O			✓	✓							✓		
44. Are equipment numbers and/or nomenclature used in the procedure identical to those displayed on the equipment?	O		✓	✓								✓		
45. If the answer to Item #44 is yes, is equipment nomenclature typed in upper case letters in the procedure?	O	✓												✓
46. Does the procedure identify the location of each item of equipment adequately? (Observe whether the operator can locate switches, gauges, etc. in a timely manner.)	O			✓						✓				

APPENDIX B

EMERGENCY PROCEDURE EVALUATION CHECKLIST

EMERGENCY PROCEDURE EVALUATION CHECKLIST

Procedure Title/No._____

Revision_____Reviewed by_____Date_____

Review the procedure for each of the following characteristics. If it possesses the characteristic, check Yes; if it lacks the characteristic, check No. Check N/A (Not Applicable) if the characteristic does not apply to the procedure.

The ratings A, B, C, and D indicate the relative impact of a characteristic on the reliability of operator performance under various levels of stress. If a procedure is deficient in a characteristic rated A, performance deviations are most likely; if a procedure is deficient in a characteristic rated D, performance deviations are least likely.

Perform Document Review Evaluation for Items #1—#38.

Item	Rating	Yes	No	N/A
1. Does the title describe the emergency for which the procedure is provided?	C	__	__	__
2. Does each page provide the following identification information?	D	__	__	__
1. Procedure number and/or title				
2. Date of issue				
3. Revision number				
4. Page number				
3. Is the last page of the procedure clearly identifiable by marking, e.g., Page____of____; Final Page?	D	__	__	__
4. If this is a temporary procedure, is it clearly marked with the expiration date?	C	__	__	__
5. Do the immediate operator actions avoid referencing operators to other procedures for instructions?	B	__	__	__

Item	Rating	Yes	No	N/A
6. Are the titles and numbers of all referenced documents identified correctly? (If the Procedure refers personnel to other procedures for instructional information, each reference must be evaluated as an independent procedure starting with Item #1 of the checklist.)	C	__	__	__
7. If this is a multiple unit site, does the procedure refer to one unit only?	B	__	__	__
8. If more than one person is required to perform the procedure, is the procedure written to one "primary" user? That is, is it clear from the way that instructions are written that one person is responsible for coordinating the activity?	B	__	__	__
9. When communication between personnel is required, does the procedure specify how and to whom?	B	__	__	__
10. Does the procedure contain provisions for coordinating the activities of others? For example, is there a checklist for recording that someone has been directed to take an action and for recording that the action has been completed?	B	__	__	__
11. Does the procedure contain provisions for verifying that symptoms associated with the emergency were actually observed? For example, is there a checklist for recording that a symptom was observed?	B	__	__	__
12. Does the procedure contain provisions for verifying that automatic actions associated with the emergency were actually observed? For example, is there a checklist for recording that an automatic action was observed?	B	__	__	__
13. Does the procedure contain provisions for verifying that critical immediate operator actions performed from memory were actually performed? For example, is there a checklist for recording that an immediate action was performed?	B	__	__	__
14. Are the instructions typed in both upper and lower case letters (as conventionally used) as opposed to all upper case letters?	C	__	__	__
15. Are instructions written in short, concise, identifiable steps as opposed to multi-step paragraphs?	A	__	__	__

Item	Rating	Yes	No	N/A
16. Are steps that must be performed in a fixed sequence clearly identified to the user? For example, are the steps marked with asterisks or is the sequence marked "Mandatory" or "Step-by-Step", etc.?	B	___	___	___
17. If a step contains more than two objects of action, are they listed rather than imbedded in the sentence? For example, if an operator is directed to close three or more valves, they should be listed rather than strung out in a sentence.	B	___	___	___
18. If cautions are applicable to the performance of specific steps or series of steps, are they placed immediately ahead of the step(s) to which they apply?	B	___	___	___
19. Are cautions separate and easily discriminable in appearance from instructional steps? For example, are they enclosed in boxes, typed in bold face letters, headed with the word CAUTION, etc.?	B	___	___	___
20. Do cautions avoid the use of action statements? (Statements directing personnel to perform actions must not be imbedded in cautions. Cautions should be expressed in the passive voice.)	B	___	___	___
21. Are cautions provided to inform personnel when displays are based on secondary sensing modes?	A	___	___	___
22. If explanations, i.e., notes, are applicable to the performance of specific steps or series of steps, are they placed immediately ahead of the step(s) to which they apply?	C	___	___	___
23. Are explanations separate and easily discriminable in appearance from instructional steps? For example, are they enclosed in boxes, typed in bold face letters, headed with the word NOTE, etc.?	C	___	___	___
24. Do explanatory notes avoid the use of action statements? (Statements directing personnel to perform actions must not be imbedded in explanatory notes.)	B	___	___	___
25. Are acceptance criteria and limits expressed in quantitative terms when possible?	B	___	___	___
26. Are quantitative acceptance criteria and limits expressed as ranges as opposed to point values?	C	___	___	___
27. Are the acceptance criteria and limits compatible with the limits stated in requirements documents?	A	___	___	___

Item	Rating	Yes	No	N/A
28. Does the procedure provide instructions for all reasonable contingencies? For example, if equipment is operating outside the range specified by the procedure, is the operator instructed what action to take?	A	__	__	__
29. Are the contingencies provided for in the procedure based upon engineering failure analyses?	A	__	__	__
30. Are contingency instructions expressed so that the contingency precedes the action statement? For example, a contingency instruction should be written "If____, do__ .", not "Do____ if____."	A	__	__	__
31. Are contingency instructions easy to understand? For example, if three or more contingencies must be met before action is directed, the contingencies should be listed separately from the action statement and ahead of the action statement.	A	__	__	__
32. If calculations are required, is space provided in the procedure to perform the computations and to record the results?	C	__	__	__
33. Are computations based on technically accurate, complete, and up-to-date formulas?	A	__	__	__
34. Are graphs, charts, and tables adequate for readability and interpolation or extraction of values?	A	__	__	__
35. Complexity Index (CI): Evaluate the complexity of the instructions by determining the average number of actions per step that the user is directed to perform. Use all steps to calculate the average. Is the average number of actions per step 1.5 or less?	B	__	__	__
36. Specificity Index (SI): Evaluate the level of specificity of the instructions by determining the percent of steps in the procedure that meet all of the following criteria. Use all steps in calculating the percent. 1. The action to be taken is specifically identified (open, close, rotate, etc.). 2. Limits are expressed quantitatively, e.g., 2 turns, 80 (75-85) in. lbs. 3. Equipment and parts are identified completely (HPCI-MO-17, etc.).				
Do 90% of the steps meet the above criteria?	B	__	__	__

Item	Rating	Yes	No	N/A
37. Do the alignment instructions in the procedure meet all of the following criteria? 1. Each item requiring alignment is individually specified. (It is not acceptable to refer personnel to previous steps.) 2. Each item is identified with a unique number or nomenclature. 3. The position in which the item is placed is specified. 4. The position in which the item is placed is verified.	B	___	___	___
38. If the procedure specifies an action that must be performed at a later time or repeated at periodic intervals, does it contain provisions for flagging the operator to perform the action? For example, if an action must be repeated every 15 minutes, are there spaces to record the times at which the action must be performed?	A	___	___	___

Perform Operator Walk-Through for Items #39—#46.

39. Does the procedure identify all likely symptoms or combinations of symptoms associated with the emergency? (If an engineering analysis is not available, determine whether the operator can describe symptoms or combinations not identified by the procedure.)	A	___	___	___
40. Does the procedure specify automatic actions associated with the emergency adequately? (Determine whether the operator can describe automatic actions not specified by the procedure.)	A	___	___	___
41. Does the procedure specify all critical actions required to respond to the emergency? (Observe whether the operator performs critical actions not specified by the procedure.)	A	___	___	___
42. If the procedure contains sequence-critical actions, is the sequence specified by the procedure correct? (Observe whether the operator performs sequence-critical actions in the sequence specified.)	A	___	___	___

Item	Rating	Yes	No	N/A
43. Does the procedure allow enough time to perform time-critical actions? (Observe whether the operator can perform time-critical actions in the time allowed, i.e., by equipment response, distances involved, etc.)	A	___	___	___
44. Are equipment numbers and/or nomenclature used in the procedure identical to those displayed on the equipment?	B	___	___	___
45. If the answer to Item #44 is Yes, is equipment nomenclature typed in upper case letters in the procedure?	C	___	___	___
46. Does the procedure identify the location of each item of equipment adequately? (Observe whether the operator can locate switches, gauges, etc, in a timely manner.)	A	___	___	___

Action: _____

_____

_____

Disposition: _____

_____

_____

APPENDIX C

EXPLANATION OF CHECKLIST ITEMS

EXPLANATION OF CHECKLIST ITEMS

Appendix C lists the procedures evaluation criteria in the same sequence in which they appear on the checklist. In cases where the relationship between a criterion and the quality of human performance might not be apparent, an explanation is provided.

1. Does the title describe the emergency for which the procedure is provided?

Explanation. Several LERs have occurred because operators selected and used a wrong procedure to perform an activity. The use of descriptive titles will increase the probability of selecting the correct procedure.

2. Does each page provide the following identification information?
    1. Procedure number and/or title
    2. Date of issue
    3. Revision number
    4. Page number

Explanation. None.

3. Is the last page of the procedure clearly identifiable by marking, e.g., Page____of____; Final Page, Last Page?

Explanation. The last page of a procedure is most vulnerable to becoming detached and lost. It should be made obvious to the user if the last page is missing.

4. If this is a temporary procedure, is it clearly marked with the expiration date?

Explanation. None.

5. Do the immediate operator actions avoid referencing operators to other procedures for instructions?

Explanation. One of the most frequently voiced complaints of operators about procedures is the overuse of references to other procedures for instructional information. In some cases the other procedures may not be obtained and used. To ensure the ready availability of information for the learning and performance of immediate operator actions, all critical information should be provided by one procedure

only.

6. Are the titles and numbers of all referenced documents identified correctly? If the procedure refers personnel to other procedures for instructional information, each reference must be evaluated as an independent procedure starting with Item #1 of the checklist.

Explanation. None.

7. If this is a multiple unit site, does the procedure refer to one unit only?

Explanation. The practice of providing one procedure containing multiple sets of equipment identification numbers for use with two or more units is quite common. This practice increases the difficulty of reading and comprehending the procedure, particularly during stressful circumstances. It also increases the probability of performing a procedure on the wrong unit.

8. If more than one person is required to perform the procedure, is the procedure written to one 'primary' user? That is, is it clear from the way that instructions are written that one person is responsible for coordinating the activity?

Explanation. The findings from the several TMI-2 studies underlined the need for more structured coordination of crew responses to emergencies. The study on which the checklist is based disclosed considerable variability among plants and among shift supervisors within a given plant with respect to training and skills in coordinating crew responses. Procedural formats to structure multi-man activities have been developed and used effectively for many years. The application of a similar procedural structure to nuclear power plant emergency procedures would reduce the number of errors in communication and in omissions of actions that currently result from relatively unstructured, uncoordinated crew responses. Because the emergency procedures are used for training as well as on-the-job application, they could also contribute to the development of relevant skills.

9. When communication between personnel is required, does the procedure specify how and to whom?

Explanation. See explanation for Item #8.

10. Does the procedure contain provisions for coordinating the activities of others? For example, is there a checklist for recording that someone has been directed to take an action and for recording that the action has been completed?

Explanation. High-stress conditions are conducive to errors in communications and omission of actions, particularly when the activities of several individuals, sometimes remote from each other, must be coordinated. A checklist or other device will aid in the early detection of these errors.

11. Does the procedure contain provisions for verifying that symptoms associated with the emergency were actually observed? For example, is there a checklist for recording that a symptom was observed?

Explanation. See explanation for Item #13.

12. Does the procedure contain provisions for verifying that automatic actions associated with the emergency were actually observed? For example, is there a checklist for recording that an automatic action was observed?

Explanation. See explanation for Item #13.

13. Does the procedure contain provisions for verifying that critical immediate operator actions performed from memory were actually performed? For example, is there a checklist for recording that an immediate action was performed?

Explanation. The observation of symptoms and automatic actions and the performance of immediate operator actions are typically accomplished before a procedure is obtained. As a result, reliance must be placed upon operator memory (unless automatic recording equipment is available and operable) to reconstruct the course of an event. The checklists are intended to enable the operators to record the occurrence of symptoms, automatic actions, and immediate operator actions directly after obtaining the procedure and before stress further degrades accurate recall.

The checklists enhance the detection of errors of omission.

14. Are the instructions typed in both upper and lower case letters (as conventionally used) as opposed to all upper case letters?

Explanation. Studies have shown that conventional printing can be read faster and more accurately than text printed entirely in upper case lettering. In addition, upper case lettering in the body of the text should be reserved for equipment nomenclature to aid in detecting references to equipment.

15. Are instructions written in short, concise, identifiable steps as opposed to multi-step paragraphs?

Explanation. Studies have shown that the speed of reading and the comprehension of written instructions are improved if the instructions are presented in short, concise sentences. Ideally, an instruction should consist of an action verb and the object of the action—plus action limits and object identifiers, and, if necessary, object locators. Additional information, such as that contained in explanations and descriptions, that is intended to aid the user to accomplish the action more effectively should ordinarily be presented in the form of a note preceding the action instruction.

16. Are steps that must be performed in a fixed sequence clearly identified to the user? For example, are the steps marked with asterisks or is the sequence marked "Mandatory" or "Step-by-Step", etc.?

Explanation. By its very nature, a written procedure presents steps in a sequence. In many cases, the actions can be performed in a variety of sequences to accomplish the same operation. In some operations, however, the sequence in which the actions are performed is critical. That is, only a single sequence of actions will result in acceptable accomplishment of the operation. Yet, the study team encountered only one plant in which sequence-critical steps were identified. As a result, the operators are generally required to make this distinction—even in high-stress conditions. A related consequence is that inspectors or

other personnel cannot assess operator knowedge of sequence-critical operations. Identification of sequence-critical steps would aid operator training and performance evaluation.

17. If a step contains more than two objects of action, are they listed rather than imbedded in the sentence? For example, if an operator is directed to close three or more valves, they should be listed rather than strung out in a sentence.

Explanation. This format (tabular or columnar) can be read faster and more accurately than conventional sentence structure. For example:

This		Not This
Open following valves:		Open valves XXU, XXV, XXW, XXX, XXY, AND XXZ.
XXU	XXX	
XXV	XXY	
XXW	XXZ	

18. If cautions are applicable to the performance of specific steps or series of steps, are they placed immediately ahead of the step(s) to which they apply?

Explanation. Instructional information must be presented in the order in which it is needed. If the user needs cautionary information before performing a specific action, it must be presented before the statement directing the action. Otherwise, there is a high probability that the action will be performed without the cautionary information being taken into consideration.

19. Are cautions separate and easily discriminable in appearance from instructional steps? For example, are they enclosed in boxes, typed in bold face letters, headed with the word CAUTION, etc.?

Explanation. None.

20. Do cautions avoid the use of action statements? (Statements directing personnel to perform actions must not be imbedded in cautions. Cautions should be expressed in the passive voice.)

Explanation. Cautions should not be expressed in terms of directing

users to take or not take actions. Instead, the cautions should describe the conditions or consequences of actions. The passive voice should be used. All actions should be directed in the instructional steps only. Failure to observe this rule consistently will result in the overlooking of critical actions by the operators.

21. Are cautions provided to inform personnel when displays are based on secondary sensing modes?

Explanation. In the TMI-2 event, individuals interpreted a display of switch position as if it were a display of valve position. An optimum solution to this human factors problem is to replace secondary sensing systems with primary sensing systems. A less effective, but readily available, solution is to insert cautions or notes in procedures to identify displays based on secondary sensing.

22. If explanations, i.e., notes, are applicable to the performance of specific steps or series of steps, are they placed immediately ahead of the step(s) to which they apply?

Explanation. See explanation for Item #18.

23. Are explanations separate and easily discriminable in appearance from instructional steps? For example, are they enclosed in boxes, typed in bold face letters, headed with the word NOTE, etc.?

Explanation. None.

24. Do explanatory notes avoid the use of action statements? (Statements directing personnel to perform actions must not be imbedded in explanatory notes.)

Explanation. See explanation for Item #20.

25. Are acceptance criteria and limits expressed in quantitative terms when possible?

Explanation. In this and other studies, reactor operators have expressed a need for more quantitative limits in procedures. It has also been found that operators vary among themselves with regard to their interpretation of qualitative modifiers, e.g., slow, fast, rapidly. Finally,

high-stress conditions can distort an individual's perception of slow, fast, etc. Use of quantified limits will promote standardization of responses.

26. Are quantitative acceptance criteria and limits expressed as ranges as opposed to point values?

Explanation. When equipment does not permit the setting of point values, or when a range of values is acceptable, the acceptance criteria should be expressed in terms of ranges. However, they should be expressed in a form to avoid errors of addition, subtraction, or conversion. Example:

Preferable	Not Preferable
_____to_____	_____±_____
(Best)____(_____–_____)	_____±_____%(Worst)
midpoint lower limit upper limit	

27. Are the acceptance criteria and limits compatible with the limits stated in requirements documents?

Explanation. None.

28. Does the procedure provide instructions for all reasonable contingencies? For example, if equipment is operating outside the range specified by the procedure, is the operator instructed what action to take?

Explanation. Many procedures are written as though all acceptance criteria and limits will be met. They do not address the exceptions. In the study on which the checklist is based, it was found that the procedures preceded by a formal engineering analysis covered 4.5 times as many contingencies as the emergency procedures that were not derived from engineering analyses. The implication of this finding is that the typical emergency procedure is probably incomplete with respect to contingency information. If the inspector finds that no engineering analysis was performed, the completeness of the procedure is doubtful. It is impractical for the inspector to perform an engineering analysis of

of the magnitude required to identify all contingencies that can be reasonably expected. Therefore, it may be necessary to make a partial evaluation of the procedure with the aid of the control room operating staff using an approach similar to the walk-through process described for evaluating Items #39 through #42.

29. Are the contingencies provided for in the procedure based upon engineering failure analyses?

Explanation. See explanation for Item #28.

30. Are contingency instructions expressed so that the contingency precedes the action statement? For example, a contingency instruction should be written "If____, do___.", not "Do____ if____."

Explanation. If the action instruction precedes the contingency statement, there is an increased probability that the operator will perform the action before reading the qualifying condition.

31. Are contingency instructions easy to understand? For example, if three or more contingencies must be met before action is directed, the contingencies should be listed separately from the action statement and ahead of the action statement.

Explanation. Frequently, the instruction to perform an action depends upon the presence of several conditions or combinations of conditions. In these instances the majority of the procedures reviewed provided this information in lengthy, hard-to-understand sentences. Essential contingency information could be overlooked or misinterpreted in complex sentences, particularly during high-stress conditions conducive to the impairment of comprehension. A tabular or columnar format promotes ease of comprehension. Example:

This	Not This
If any of the following conditions exist: _____ _____ _____, do_____.	If_____or_____ or_____exist, do_____.

32. If calculations are required, is space provided in the procedure to perform the computations and to record the results?

Explanation. This provision is intended to increase the accuracy of performing calculations and to facilitate verification of the results by others.

33. Are computations based on technically accurate, complete, and up-to-date formulas?

Explanation. None.

34. Are graphs, charts, and tables adequate for readability and interpolation or extraction of values?

Explanation. Misinterpretation of graphs, charts, and tables has resulted in performance errors. It is often traceable to poor readability of these materials—which, in turn, is attributable to 1) inadequate original construction, or 2) inadequate reproduction. The following guidelines are provided to evaluate readability.

Original construction. Letters and numbers should be typed rather than handwritten. Lines on graph paper should be reproducible on licensee reproduction equipment. On graphs, units of measurement used in plotted values should be compatible with divisions on graph paper. That is, if plotted values progress in units of five, e.g., 5, 10, 15, etc., it is better to separate the values by five lines than by four lines. To facilitate accuracy of locating values in charts and tables, look for such aids as 1) partitioning tables with lines, 2) arranging values in subgroups, e.g., inserting spaces between subgroups of five values, and 3) placing connecting lines between values or between nomenclature and values.

Reproduction. In some cases, copies are so many generations removed from the original or master copy that lines in graphs, charts, and tables have deteriorated or disappeared, making it difficult to track or interpolate values. Letters and numbers can undergo similar deterioration. Also, materials have sometimes been reduced in size so that readability is impaired. Letters and numbers should be at least 1/8 in. in height, unbroken and unfilled. All lines in the reproductions should be as

visible as they are in the original master copies. First, compare the reproductions to the original or master copies. Then, evaluate the readability of the reproductions under the conditions of illumination in which personnel use them.

35. Complexity Index (CI): Evaluate the complexity of the instructions by determining the average number of actions per step that the user is directed to perform. Use all steps in calculating the average. Is the average number of actions per step 1.5 or less?

Explanation. The complexity index (CI) of a procedure is defined as the average number of actions stated in the instructional steps or paragraphs. The average is computed by sampling all steps or paragraphs in a procedure.

$$CI = \frac{\text{Number of Actions in Procedure}}{\text{Number of Steps or Paragraphs in Procedure}}$$

The greater the number of actions that are directed by a step, the more likely an action is to be overlooked or forgotten. Ideally, a step should contain only one action unless the actions are related, in which case up to three actions are acceptable. Related actions are actions that, in combination, accomplish a single end-result. In the example of related actions shown below, the single result is an adjusted volume.

Example of Three Related Actions (Acceptable):

"5. Start pump PL-16. Observe gauge WL-16. When level is 62 (60-64) in., stop pump."

Example of Two Unrelated Actions (Not Acceptable):

"8. Close switch LAC-1781. Close valve HVC-23."

36. Specificity Index (SI): Evaluate the level of specificity of the instructions by determining the percent of steps in the procedure that meet all of the following criteria. Use all steps in calculating the percent.

1. The action to be taken is specifically identified (open,

close, rotate, etc.).

2. Limits are expressed quantitatively, e.g., 2 turns, 80 (75-85) in. lbs.
3. Equipment and parts are identified completely (HPCI-MO-17, etc.)

Do 90% of the steps meet the above criteria?

Explanation. The above criteria list the basic characteristics of a specific (versus general) instruction. Fewer errors of interpretation or omission result from instructions with high specificity.

37. Do the alignment instructions in the procedure meet all of the following criteria?
    1. Each item requiring alignment is individually specified. (It is not acceptable to refer personnel to previous steps.)
    2. Each item is identified with a unique number or nomenclature.
    3. The position in which the item is to be placed is specified.
    4. The position in which the item is placed is verified.

Explanation. Two of the primary contributors to misalignment are lack of specificity of instructions and lack of physical verification of position. The criteria listed above are aimed at improving specificity and verification. In some procedures, it was found that instructions were adequate for initial alignment but shortchanged realignment by simply directing personnel to "Reposition valves listed in Step 5." In this instance, personnel were not provided a means within the procedure for verifying valve position. The instruction should have relisted the valves, their new positions, and provided signoff for each valve.

38. If the procedure specifies an action that must be performed at a later time or repeated at periodic intervals, does it contain provisions for flagging the operator to perform the action? For example, if an action must be repeated every 15 minutes, are there spaces to record the times at which the action must be performed?

Explanation. Some emergency procedures require that an action such as checking a pressure or flowrate be performed at set intervals, e.g.,

every 15 minutes. In the past, failure to observe timing requirements has resulted in LERs describing overflows, excessive draining, etc. Provisions within the procedure for recording times at which time-critical actions must be performed will enable operators to comply with timing requirements more consistently and more accurately.

39. Does the procedure identify all likely symptoms or combinations of symptoms associated with the emergency? (If an engineering analysis is not available, determine whether the operator can describe symptoms or combinations not identified by the procedure.)

Explanation. See explanation for Item #41.

40. Does the procedure specify automatic actions associated with the emergency adequately? (Determine whether the operator can describe automatic actions not specified by the procedure.)

Explanation. See explanation for Item #41.

41. Does the procedure specify all critical actions required to respond to the emergency? (Observe whether the operator performs critical actions not specified by the procedure.)

Explanation. Items #39, #40, and #41 deal with the completeness of an emergency procedure. As described earlier (see explanation for Item #28), the completeness of a procedure is a function of the quality of the engineering analyses on which the procedure is based. It is likely that, in many cases, the inspector will find that no engineering analyses were performed as part of the development of the procedure being evaluated. It is also possible that some of the analyses that were performed were inadequate. Study findings comparing the amount of contingency information in procedures not derived from engineering analyses against procedures derived from engineering analyses (see Item #28) underline this possibility. The inspector is not in a position to perform engineering analyses to determine the completeness of the information in a procedure. However, a partial evaluation can be made with a relatively small investment of time with the assistance of members of the operating staff. Discussions with and observations of experienced operators performing a walk-through of the procedure should disclose

procedural omissions of highest probability events.

42. If the procedure contains sequence-critical actions, is the sequence specified by the procedure correct? (Observe whether the operator performs sequence-critical actions in the sequence specified.)

Explanation. The inspector will encounter some procedures in which sequences of actions are not critical and other procedures in which sequences are critical to successful accomplishment of an operation. In many cases, the licensee will not make this distinction obvious. As a first step, the licensee should be required to identify sequence-critical steps. The inspector can then determine the accuracy of the sequences as part of the walk-through evaluation process.

43. Does the procedure allow enough time to perform time-critical actions? (Observe whether the operator can perform time-critical actions in the time allowed, i.e., by equipment response, distances involved, etc.)

Explanation. Some actions specified in emergency procedures are time-critical. Time-critical steps should be identified by the licensee along with the time allowed to perform a step or the time allowed to intervene between steps. The inspector should then determine whether or not the operator or crew of operators can perform these steps within the allowed time limits.

44. Are equipment numbers and/or nomenclature used in the procedure identical to those displayed on the equipment?

Explanation. None.

45. If the answer to Item #44 is Yes, is equipment nomenclature typed in upper case letters in the procedure?

Explanation. It is a technical writing practice to print equipment nomenclature in capital letters. Use of this guideline enables personnel to locate and identify procedural references to equipment quickly. It also informs personnel that this is the nomenclature dis-

played on the equipment itself.

46. Does the procedure identify the location of each item of equipment adequately? (Observe whether the operator can locate switches, gauges, etc. in a timely manner.)

Explanation. Findings from TMI-2 and other studies suggest that procedures sometimes fail to provide enough location information to the operators. This deficiency can be particularly serious in an emergency during which search time might be limited. Emergency procedures should be evaluated for this characteristic as part of the walk-through.

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16. ABSTRACT (200 words or less)

This report describes the process for developing a checklist to be used by United States Nuclear Regulatory Commission, Office of Inspection and Enforcement (IE) inspectors during their evaluation of emergency procedures used in nuclear power plants. The objective of the checklist is to aid inspectors in identifying procedural characteristics that can lead to reactor operator performance deviations. Four nuclear power plants were surveyed to obtain a sample of procedures and related information for human factors evaluation. In addition, a human factors analysis of 890 LERs submitted during the period 1975 through 1978 was performed to identify the major categories of performance deviations associated with reactor operator activities. Checklist items aimed at preventing these performance deviations or facilitating their early detection were developed. The study findings supporting the procedures evaluation criteria comprising the checklist items are described in this report. A companion document, Checklist for Evaluating Emergency Procedures Used in Nuclear Power Plants, NUREG/CR-2005, SAND81-7074, has been prepared as a handbook for inspectors. It describes the checklist and provides instructions for its use.

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